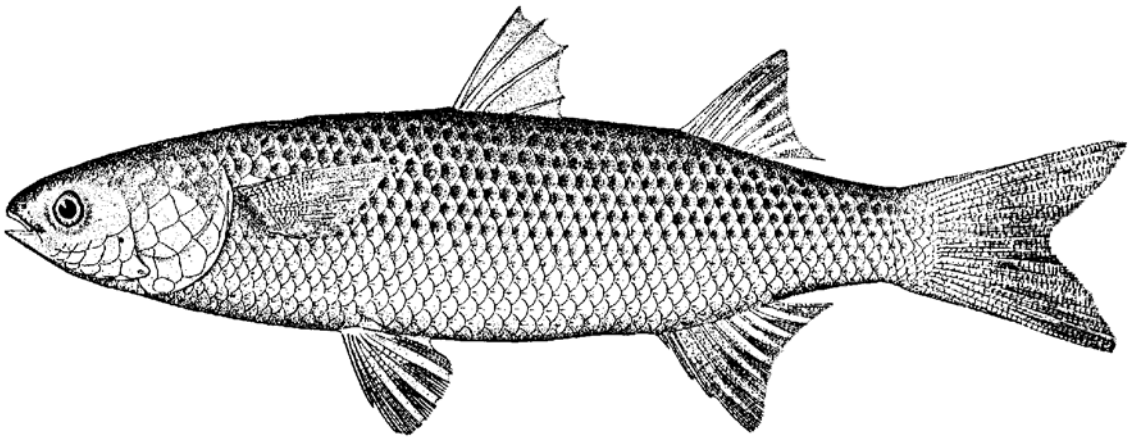
North Carolina
Fishery Management Plan

Striped Mullet



North Carolina
MARINE
FISHERIES
Dept. of Environment and Natural Resources

April 2006

North Carolina
Fishery Management Plan

Striped Mullet

North Carolina Department of Environment and Natural Resources
Division of Marine Fisheries
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April 2006

Draft adopted by Advisory Committee:	3/31/05
Draft adopted by Marine Fisheries Commission for Public Meetings:	4/21/05
Draft adopted by Marine Fisheries Commission after Public Meetings:	6/28/05
Final adopted by Marine Fisheries Commission:	4/27/06

1. ACKNOWLEDGMENTS

The 2005 North Carolina Striped Mullet Fishery Management Plan (FMP) was developed under the direction of the North Carolina Marine Fisheries Commission (MFC) with the advice of the striped mullet Advisory Committee. The plan was prepared by the North Carolina Department of Environment and Natural Resources, Division of Marine Fisheries (DMF).

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3. EXECUTIVE SUMMARY

The goal of the 2005 North Carolina Striped Mullet Fishery Management Plan (FMP) is to ensure the long-term self-sustainability and sustainable harvest of the North Carolina striped mullet stock. Plan objectives include: develop an objective management program that provides conservation of the resource and sustainable harvest in the fishery; ensure that the spawning stock is of sufficient capacity to prevent recruitment-overfishing; address socio-economic concerns of all user groups; restore, improve, and protect critical habitats that affect growth, survival, and reproduction of the North Carolina striped mullet stock; evaluate, enhance, and initiate studies to increase our understanding of striped mullet biology and population dynamics in North Carolina; and promote public awareness regarding the status and management of the North Carolina striped mullet stock.

A population assessment of the North Carolina striped mullet was conducted using a forward projection analysis incorporating several fishery-dependent and independent data sets. Spawning stock biomass (SSB) has increased and the three highest estimates of age 0 recruitment occurred in the last five years, peaking in 2002. Overfishing is not occurring based on the threshold fishing mortality rate (F25% = 1.25). The stock has not been overfished since 1998 even though the female stock is heavily exploited. Females are able to mature because of low commercial fishing mortality in January-June, combined with the selectivity of older fish in July-December. Fishing mortality from recreational fishing is low with mortality occurring on age 0 fish in the summer and fall. Although overfishing is not occurring, it is currently being fished near the maximum exploitation level that can maintain sustainability. Based on this assessment no new management measures will be implemented at this time. However, minimum and maximum landings thresholds of 1.3 million pounds and 3.1 million pounds, respectively were established. If landings fall below the minimum threshold the DMF would initiate further analysis of the data to determine if the decrease in landings is attributed to stock decline or decreased fishing effort. If landings exceed the 3.1 million pounds the DMF would initiate analysis to determine if harvest is sustainable and assess what factors are driving the increase in harvest.

The proposed management strategy for the striped mullet fisheries in North Carolina is to: 1) optimize resource utilization over the long-term; 2) reduce conflict; and 3) promote public education. The first strategy will be accomplished by protecting critical habitats, and monitoring stock status. Inshore gill net conflicts will be dealt with on a case-by-case basis and management actions will be implemented to address specific fishery related problems. Prior to April 2006, user conflicts in the Atlantic Ocean were to be handled by adopting gill net restrictions on Bogue Banks currently in proclamation as Rule. Due to the sale of two of the three subject ocean fishing piers, the restrictions will remain in annually issued proclamations to maintain needed flexibility. A minimum distance requirement will be examined for the conflict between gill net and stop net in western Bogue Banks. The Division of Marine Fisheries (DMF) will work to enhance public information and education.

Issues addressed in formulating the management plan for North Carolina's striped mullet fishery encompassed the following general categories: 1) environmental degradation; 2) fishing practices; and 3) user conflicts. Specific issues and recommendations are as follows:

1) Environmental degradation: Suitable and adequate habitat is a critical element in the ecology and productivity of estuarine systems. Degradation or improvement in one aspect of habitat may have a corresponding impact on water quality. Maintenance and improvement of suitable estuarine habitat and water quality are probably the most important factors in providing sustainable striped mullet stocks. Habitat and water quality protection, conservation, and

restoration are essential to accomplish the goal and objectives of this plan.

2) Fishing issues: The bycatch of striped mullet in commercial fishing gear was quantified by analyzing fishery-dependent data, fishery-independent data, and DMF Trip Ticket data. From this it appears that the bycatch of striped mullet is not a major concern for North Carolina fishery managers at this time. A possession limit of 200 mullets (white and striped in aggregate) per person in the recreational fishery is recommended. The intent is to eliminate anglers from taking large amounts of bait mullets from North Carolina and selling them in other states without impinging on normal fishing practices. A possession limit in the recreational fishery allows Marine Patrol to distinguish between a commercial and a recreational fishing operation. Additionally, given the low fishing mortality on striped mullet juveniles estimated from the 2004 stock assessment, there is currently no biological urgency to reduce the recent levels of striped mullet bait harvest.

3) User conflicts: The change in inshore striped mullet fishing practices from traditional, passive soak nets to active tower boats with runaround nets has created conflicts with marinas and shoreline residents. Setting of gill nets around private piers and in restricted navigation areas and disruptive practices associated with night fishing have resulted in charges against the striped mullet fishermen of impeding navigation and disturbing the peace. The situation has resulted in petitions for rulemaking asking the MFC for varying degrees of gill net exclusion from specific areas. This plan recommends that inshore gill net conflicts continue to be handled on a case-by-case basis and implement management actions to address specific fishery related problems. User conflicts in the Atlantic Ocean striped mullet beach seine fishery have existed along Bogue Banks since the mid 1980s and have involved allocation issues between commercial gill netters and the stop net crews, and between the ocean fishing pier owners, pier patrons and stop net crews. Although not as intense as in years past, these confrontations still occur. It was recommended that the MFC adopt gill net restrictions on Bogue Banks currently in proclamation as Rule. As of April, 2006, due to the sale of two of the three subject ocean fishing piers, proclamation authority needs to be maintained. It is premature to put the stop net proclamation measures into Rule because of the upcoming NMFS Bottlenose Dolphin Take Reduction Plan (BDTRP) restrictions and the changing nature of the beach seine mullet fishery. Flexibility needs to be maintained for stop net setting sites and gear parameters.

4. INTRODUCTION

4.1 LEGAL AUTHORITY FOR MANAGEMENT

Fisheries management includes all activities associated with maintenance, improvement, and utilization of the fisheries resources of the coastal area, including research, development, regulation, enhancement, and enforcement.

All authority for management of North Carolina's striped mullet fishery is vested in the State of North Carolina. Management of the striped mullet fishery includes all activities associated with maintenance, improvement, and utilization of the striped mullet population and their habitats in the coastal area, including research, development, regulation, enhancement, and enforcement. Most striped mullet harvest occurs from coastal waters and is under rules of the North Carolina Marine Fisheries Commission (MFC); there is limited harvest from inland waters under the jurisdiction of the North Carolina Wildlife Resources Commission. However, the North Carolina Department of Environment and Natural Resources (DENR) is the agency directed by North Carolina General Statute 113-182.1 (G.S. 113-182.1) to prepare Fishery Management Plans for all commercially or recreationally significant species or fisheries that comprise State marine or estuarine resources. These plans must be approved and adopted by the MFC.

Many different state laws (General Statutes - G.S.) provide the necessary authority for fishery management in North Carolina. General authority for stewardship of the marine and estuarine resources by the DENR is provided in G.S. 113-131. The Division of Marine Fisheries (DMF) is the branch of the DENR that carries out this responsibility. G.S. 113-136 provides enforcement authority for DMF Marine Patrol officers. General Statute 113-163 authorizes research and statistical programs. The MFC is charged to "manage, restore, develop, cultivate, conserve, protect, and regulate the marine and estuarine resources of the State of North Carolina" (G.S. 143B-289.51). The MFC can regulate fishing times, areas, fishing gear, seasons, size limits, and quantities of fish harvested and possessed (G.S. 113-182 and 143B-289.52). General Statute 143B-289.52 allows the MFC to delegate authority to implement its regulations for fisheries "which may be affected by variable conditions" to the Director of DMF by issuing public notices called "proclamations". Thus, North Carolina has a very powerful and flexible legal basis for coastal fisheries management. The General Assembly has retained for itself the authority to establish commercial fishing licenses and mandates that there will be no fees charged for permits. It has delegated to the MFC authority to establish permits for various commercial fishing activities.

The Fisheries Reform Act of 1997 (FRA) establishes a process for preparation of coastal fisheries management plans in North Carolina (G.S. 113-182). The Act was amended in 1998 and again in 2004. The FRA states that "the goal of the plans shall be to ensure the long-term viability of the State's commercially and recreationally significant species or fisheries. Each plan shall be designed to reflect fishing practices so that one plan may apply to a specific fishery, while other plans may be based on gear or geographic areas. Each plan shall:

a. Contain necessary information pertaining to the fishery or fisheries, including management goals and objectives, status of the relevant fish stocks, stock assessments for multi-year species, fishery habitat and water quality considerations consistent with Coastal Habitat Protection Plans adopted pursuant to G.S. 143B-279.8, social and economic impact of the fishery to the State, and user conflicts.

b. Recommend management actions pertaining to the fishery or fisheries.

c. Include conservation and management measures that will provide the greatest overall benefit to the State, particularly with respect to food production, recreational opportunities, and the protection of marine ecosystems, and will produce a sustainable harvest, and

d. Specify a time period, not to exceed 10 years from the date of adoption of the plan, for ending overfishing and achieving a sustainable harvest. This subdivision shall apply only to a plan for a fishery that is overfished. This subdivision shall not apply to a plan for a fishery where the biology of the fish or environmental conditions make ending overfishing and achieving a sustainable harvest within 10 years impracticable.

Sustainable harvest is defined in the FRA as "The amount of fish that can be taken from a fishery on a continuing basis without reducing the stock biomass of the fishery or causing the fishery to become overfished". Overfished is defined as the condition of a fishery that occurs when the spawning stock biomass of the fishery is below the level that is adequate to replace the spawning class of the fishery. Overfishing is defined as fishing that causes a level of mortality that prevents a fishery from producing a sustainable harvest.

4.2 RECOMMENDED MANAGEMENT PROGRAM

4.2.1 Goals and objectives

The goal of the 2005 striped mullet Fishery Management Plan is to ensure the long-term self-sustainability and sustainable harvest of the North Carolina striped mullet stock.

Objectives:

1. Develop an objective management program that provides conservation of the resource and sustainable harvest in the fishery.

2. Ensure that the spawning stock is of sufficient capacity to prevent recruitment-overfishing.

3. Address socio-economic concerns of all user groups.

4. Restore, improve, and protect critical habitats that affect growth, survival, and reproduction of the North Carolina striped mullet stock.

5. Evaluate, enhance, and initiate studies to increase our understanding of striped mullet biology and population dynamics in North Carolina.

6. Promote public awareness regarding the status and management of the North Carolina striped mullet stock.

4.2.2 Sustainable harvest

Sustainable harvest will be achieved with a female commercial fishing mortality threshold and target based on SPR = 25% and SPR = 30% (Figure 4.1). Fishing mortality has been at or below the threshold since 1999.

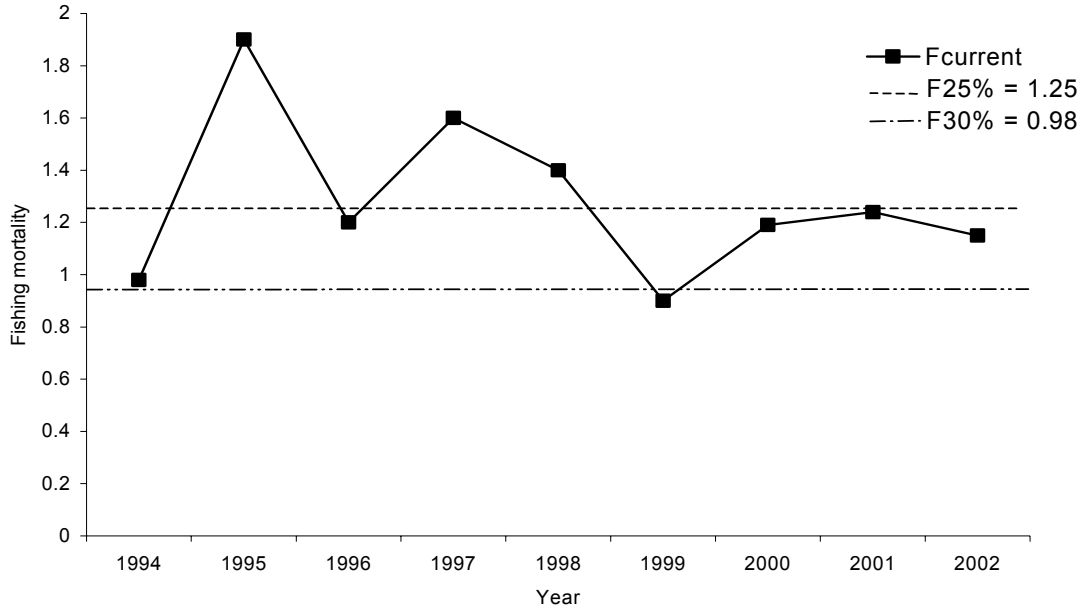

Figure 4.1. Striped mullet female fishing mortality (1994-2002) in relation to F_{Target} ($F_{30\%}$) and $F_{Threshold}$ ($F_{25\%}$).

4.2.3 Management strategy

The proposed management strategy for the striped mullet fisheries in North Carolina is to 1) optimize resource utilization over the long-term, 2) reduce conflict, and 3) promote public education. The first strategy will be accomplished by protecting critical habitats, and monitoring stock status. Inshore gill net conflicts will be dealt with on a case-by-case basis and management actions will be implemented to address specific fishery related problems. Prior to April 2006, user conflicts in the Atlantic Ocean were to be handled by adopting current gill net restrictions on Bogue Banks that currently are in proclamation as Rule. Due to the sale of two of the three subject ocean fishing piers, the restrictions will remain in annually issued proclamations to maintain needed flexibility. A minimum distance requirement will be examined for the conflict between gill netters and stop netters in western Bogue Banks. The DMF will work to enhance public information and education.

4.3 DEFINITION OF MANAGEMENT UNIT

The management unit for the North Carolina striped mullet FMP includes all striped mullet within the coastal and joint waters of North Carolina.

4.4 GENERAL PROBLEM(S) STATEMENT

4.4.1 Environmental degradation

Suitable and adequate habitat is a critical element in the ecology and productivity of estuarine systems. Degradation or improvement in one aspect of habitat may have a corresponding impact on water quality. Maintenance and improvement of suitable estuarine habitat and water quality are probably the most important factors in providing a sustainable striped mullet stock. Habitat and water quality protection, conservation, and restoration are essential to accomplish the goal and objectives of this plan.

4.4.2 Fishing issues

The bycatch of striped mullet in commercial fishing gear was quantified by analyzing fishery-dependent data, fishery-independent data, and DMF Trip Ticket data. From this it appears that the bycatch of striped mullet is not a major concern for North Carolina fishery managers at this time. A possession limit of 200 mullets (white and striped in aggregate) per person in the recreational fishery is recommended. The intent is to eliminate anglers from taking large amounts of bait mullets from North Carolina and selling them in other states without impinging on normal fishing practices. A possession limit in the recreational fishery allows Marine Patrol to distinguish between a commercial and a recreational fishing operation. In addition, given the low fishing mortality on striped mullet juveniles estimated from the 2004 stock assessment, there is currently no biological urgency to reduce the recent levels of striped mullet bait harvest.

4.4.3 User conflicts

The change in inshore striped mullet fishing practices from traditional, passive soak nets to active tower boats with runaround nets has created conflicts with marinas and shoreline residents. Setting of gill nets around private piers and in restricted navigation areas and disruptive practices associated with night fishing have resulted in charges against the striped mullet fishermen of impeding navigation and disturbing the peace. The situation has resulted in petitions for rulemaking asking the MFC for varying degrees of gill net exclusion from specific areas. Inshore gill net conflicts should continue to be handled on a case-by-case basis and management actions implemented to address specific fishery related problems. User conflicts in the Atlantic Ocean striped mullet beach seine fishery have existed along Bogue Banks since the mid 1980s and have involved allocation issues between commercial gill netters and stop net crews, and between the ocean fishing pier owners, pier patrons and stop net crews. Although not as intense as in years past, these confrontations still occur. Prior to April 2006, user conflicts in the Atlantic Ocean were to be handled by adopting gill net restrictions on Bogue Banks currently in proclamation as Rule. Due to the sale of two of the three subject ocean fishing piers, the restrictions will remain in annually issued proclamations to maintain needed flexibility. It is premature to put the stop net proclamation measures into Rule because of the upcoming NMFS restrictions and the changing nature of the beach seine striped mullet fishery. Flexibility needs to be maintained for stop net setting sites and gear parameters.

4.5 EXISTING PLANS STATUTES, AND RULES

4.5.1 Plans

Currently there are no state or federal Fishery Management Plans for striped mullet along the U.S. Atlantic Coast.

4.5.2 Statutes

All management authority for North Carolina's striped mullet fishery is vested in the State of North Carolina. Statutes that have been applied to the striped mullet fishery include:

- It is unlawful to fish in the ocean from vessels or with a net within 750 feet of a properly licensed and marked fishing pier. G.S. 113-185
- It is unlawful to engage in trash or scrap fishing (the taking of young of edible fish before they are of sufficient size to be of value as individual food fish) for commercial disposition as bait, for sale to any dehydrating or nonfood processing plant, or for sale or commercial disposition in any manner. The MFC's rules may authorize the disposition of the young of edible fish taken in connection with the legitimate commercial fishing operations, provided it is a limited quantity and does not encourage "scrap fishing". G.S. 113-185
- It is unlawful for any person without the authority of the owner of the equipment to take fish from nets, traps, pots, and other devices to catch fish, which have been lawfully placed in the open waters of the State. G.S. 113-268 (a)
- It is unlawful for any vessel in the navigable waters of the State to willfully, wantonly, and unnecessarily do injury to any seine, net or pot. G.S. 113-268 (b)
- It is unlawful for any person to willfully destroy or injure any buoys, markers, stakes, nets, pots, or other devices or property lawfully set out in the open waters of the State in connection with any fishing or fishery. G.S. 113-268 (c)
- It is unlawful to use spotter planes in an operation that takes food fish. G.S. 113-171.1.

4.5.3 Marine Fisheries Commission Rules

The following rules adopted by the MFC affect management of striped mullet stocks in North Carolina. The version of the rules shown below is taken from North Carolina Fisheries Rules for Coastal Waters effective January 1, 2003. These rules are codified in Title 15A Chapter 3 of the North Carolina Administrative Code (15A NCAC 03).

SUBCHAPTER 03J – NETS, POTS, DREDGES, AND OTHER FISHING DEVICES

SECTION .0100 – NET RULES, GENERAL

.0101 FIXED OR STATIONARY NETS

It is unlawful to use or set fixed or stationary nets:

(1) In the channel of the Intracoastal Waterway or in any other location where it may constitute a hazard to navigation;

(2) So as to block more than two-thirds of any natural or manmade waterway, sound, bay, creek, inlet or any other body of water;

(3) In the middle third of any marked navigation channel;

(4) In the channel third of the following rivers: Roanoke, Cashie, Middle, Eastmost, Chowan, Little, Perquimans, Pasquotank, North, Alligator, Pungo, Pamlico, and Yeopim.

History Note: Authority G.S. 113-134; 113-182; 143B-289.52;
Eff. January 1, 1991.

.0103 GILL NETS, SEINES, IDENTIFICATION, RESTRICTIONS

(a) It is unlawful to use a gill net with a mesh length less than 2½ inches.

(b) The Fisheries Director may, by proclamation, limit or prohibit the use of gill nets or seines in coastal waters, or any portion thereof, or impose any or all of the following restrictions on the use of gill nets or seines:
   (1) Specify area.
   (2) Specify season.
   (3) Specify gill net mesh length.
   (4) Specify means/methods.
   (5) Specify net number and length.

(c) It is unlawful to use fixed or stationary gill nets in the Atlantic Ocean, drift gill nets in the Atlantic Ocean for recreational purposes, or any gill nets in internal waters unless nets are marked by attaching to them at each end two separate yellow buoys which shall be of solid foam or other solid buoyant material no less than five inches in diameter and no less than five inches in length. Gill nets which are not connected together at the top line shall be considered as individual nets, requiring two buoys at each end of each individual net. Gill nets connected together at the top line shall be considered as a continuous net requiring two buoys at each end of the continuous net. Any other marking buoys on gill nets used for recreational purposes shall be yellow except one additional buoy, any shade of hot pink in color, constructed as specified in Paragraph (c) of this Rule, shall be added at each end of each individual net. Any other marking buoys on gill nets used in commercial fishing operations shall be yellow except that one additional identification buoy of any color or any combination of colors, except any shade of hot pink, may be used at either or both ends. The owner shall always be identified on a buoy on each end either by using engraved buoys or by attaching engraved metal or plastic tags to the buoys. Such identification shall include owner's last name and initials and if a vessel is used, one of the following:
   (1) Owner's N.C. motor boat registration number, or
   (2) Owner's U.S. vessel documentation name.

(d) It is unlawful to use gill nets:
   (1) Within 200 yards of any pound net with lead and pound or heart in use;
   (2) From March 1 through October 31 in the Intracoastal Waterway within 150 yards of any railroad or highway bridge.

(e) It is unlawful to use gill nets within 100 feet either side of the center line of the Intracoastal Waterway Channel south of Quick Flasher No. 54 in Alligator River at the southern entrance to the Intracoastal Waterway to the South Carolina line, unless such net is used in accordance with the following conditions:
   (1) No more than two gill nets per boat may be used at any one time;
   (2) Any net used must be attended by the fisherman from a boat who shall at no time be more than 100 yards from either net; and
   (3) Any individual setting such nets shall remove them, when necessary, in sufficient time to permit unrestricted boat navigation.

(f) It is unlawful to use drift gill nets in violation of 15A NCAC 03J .0101(2) and Paragraph (e) of this Rule.

(g) It is unlawful to use unattended gill nets with a mesh length less than five inches in a commercial fishing operation in the following areas:
   (1) Pamlico River, west of a line beginning at a point on Mauls Point at 35° 26.9176'

N - 76° 55.5253’ W; to a point on Ragged Point at 35° 27.5768’ N - 76° 54.3612’ W;

(2) Within 200 yards of any shoreline in Pamlico River and its tributaries east of the line from Mauls Point at 35° 26.9176’ N - 76° 55.5253’ W; to Ragged Point at 35° 27.5768' N - 76° 54.3612' W and west of a line beginning at a point on Pamlico Point at 35° 18.5906' N - 76° 28.9530' W ; through Marker #1 to a point on Roos Point at 35° 22.3622' N - 76° 28.2032' W;

(3) Pungo River, east of a line beginning at a point on Durants Point at 35° 30.5312' N - 76° 35.1594' W; to the northern side of the breakwater at 35° 31.7198' N - 76° 36.9195' W;

(4) Within 200 yards of any shoreline in Pungo River and its tributaries west of the line from Durants Point at 35° 30.5312' N - 76° 35.1594' W; to the northern side of the breakwater at 35° 31.7198' N - 76° 35.1594' W, and west of a line beginning at a point on Pamlico Point at 35° 18.5906' N - 76° 28.9530' W; through Marker #1 to a point on Roos Point at 35° 22.3622' N - 76° 28.2032' W;

(5) Neuse River and its tributaries northwest of the Highway 17 highrise bridge;

(6) Trent River and its tributaries;

(7) Within 200 yards of any shoreline in Neuse River and its tributaries east of a line from the Highway 17 highrise bridge and west of a line beginning at a point on Wilkinson Point at 34° 57.9116' N - 76° 48.2240' W; to a point on Cherry Point at 34° 56.3658' N - 76° 48.7110' W.

(h) It is unlawful to use unattended gill nets with a mesh length less than five inches in a commercial fishing operation from May 1 through October 31 in the following internal coastal and joint waters of the state south of a line beginning at a point on Roanoke Marshes Point at 35° 48.3693' N - 75° 43.7232' W; to a point on Eagle Nest Bay at 35° 44.1710' N - 75° 31.0520' W to the South Carolina State Line:

(1) All primary nursery areas described in 15A NCAC 03R .0103, all permanent secondary nursery areas described in 15A NCAC 03R .0104, and no trawl areas described in 15A NCAC 03R .0106 (3),(4),(6), and (7);

(2) In the area along the Outer Banks, beginning at a point on Core Banks at 34° 58.7853' N - 76° 09.8922' W; to a point on Wainwright Island at 34° 59.4664' N - 76° 12.4859' W; to a point at 35° 00.2666' N - 76° 12.2000' W; to a point near Beacon “HL” at 35° 01.5833' N - 76° 11.4500' W; to a point near North Rock at 35° 06.4000' N - 76° 04.3333' W; to a point near Nine Foot Shoal Channel at 35° 08.4333' N - 76° 02.5000' W; to a point near the west end of Clark Reef at 35° 09.3000' N - 75° 54.8166' W; to a point south of Legged Lump at 35° 10.9666’ N – 75° 49.7166’ W; to a point on Legged Lump at 35° 11.4833’ N – 75° 51.0833’ W; to a point near No. 36 in Rollinson Channel at 35° 15.5000’ N – 75° 43.4000’ W; to a point near No. 2 in Cape Channel at 35° 19.0333' N - 75° 36.3166' W; to a point near No. 2 in Avon Channel at 35° 22.3000’ N – 75° 33.2000’ W; to a point on Gull Island at 35° 28.4500' N - 75° 31.3500' W; to a point west of Salvo at 35° 32.6000’ N – 75° 31.8500’ W; to a point west of Rodanthe Pier at 35° 35.0000’ N – 75° 29.8833’ W; to a point near No. 2 in Chicamacomico Channel, to a point west of Beach Slough at 35° 40.0000’ N – 75° 32.8666’ W; to a point west of Pea Island at 35° 45.1833' N - 75° 34.1000' W; to a point at 35° 44.1710’ N - 75° 31.0520’ W. Thence running south along the shoreline across the inlets to the point of beginning;

(3) In Back and Core sounds, beginning at a point on Shackleford Banks at 34° 39.6601' N - 76° 34.4078' W; to a point at Marker #3 at 34° 41.3166' N - 76° 33.8333' W; to a point at 34° 40.4500' N - 76° 30.6833' W; to a point near Marker “A37" at 34° 43.5833' N - 76° 28.5833' W; to a point at 34° 43.7500' N -

76° 28.6000' W; to a point at 34° 48.1500' N - 76° 24.7833' W; to a point near Drum Inlet at 34° 51.0500' N - 76° 20.3000' W; to a point at 34° 53.4166' N - 76° 17.3500'; to a point at 34° 53.9166' N - 76° 17.1166' W; to a point at 34° 53.5500' N - 76° 16.4166' W; to a point at 34° 56.5500' N - 76° 13.6166' W; to a point at 34° 56.4833' N - 76° 13.2833' W; to a point at 34° 58.1833' N - 76° 12.3000' W; to a point at 34° 58.8000' N - 76° 12.5166' W; to a point on Wainwright Island at 34° 59.4664' N - 76° 12.4859' W; to a point on Core Banks at 34° 58.7832' N - 76° 09.8922' W; thence following the shoreline south across Drum and Barden inlets to the point of beginning;

(4) Within 200 yards of any shoreline, except from October 1 through October 31, south and east of Highway 12 in Carteret County and south of a line from a point on Core Banks at 34° 58.7853' N - 76° 09.8922' W; to Camp Point at 35° 59.7942' N - 76° 14.6514' W to the South Carolina State Line.

History Note: Authority G.S. 113-134; 113-173; 113-182; 113-221; 143B-289.52
Eff. January 1, 1991;
Amended Eff. August 1, 1998; March 1, 1996; March 1, 1994; July 1, 1993; September 1, 1991;
Temporary Amendment Eff. October 2, 1999; July 1, 1999; October 22, 1998;
Amended Eff. April 1, 2001.
Temporary Amendment Eff. May 1,2001;
Amended Eff. August 1, 2002.

SECTION .0400 – FISHING GEAR

.0402 FISHING GEAR RESTRICTIONS

(a) It is unlawful to use commercial fishing gear in the following areas during dates and times specified for the identified areas:

(1) Atlantic Ocean - Dare County:

(A) Nags Head:

(i) Seines and gill nets may not be used from the North Town Limit of Nags Head at Eight Street southward to Gulf Street:

(I) From Wednesday through Saturday of the week of the Nags Head Surf Fishing Tournament held during October of each year the week prior to Columbus Day.

(II) From November 1 through December 15.

(ii) Commercial fishing gear may not be used within 750 feet of licensed fishing piers when open to the public.

(B) Oregon Inlet. Seines and gill nets may not be used from the Friday before Easter through December 31:

(i) Within one-quarter mile of the beach from the National Park Service Ramp #4 (35° 48' 15" N - 75° 32' 42" W) on Bodie Island to the northern terminus of the Bonner Bridge (35° 46' 30" N - 75° 32' 22" W) on Hwy. 12 over Oregon Inlet.

(ii) Within the area known locally as "The Pond", a body of water generally located to the northeast of the northern terminus of the Bonner Bridge.

(C) Cape Hatteras (Cape Point). Seines and gill nets may not be used within one-half mile of Cape Point from the Friday before Easter through December 31. The closed area is defined by a circle with a one-half mile radius having the center at Cape Point (35° 12' 54" N - 75° 31' 43" W).

The closed area begins one-half mile north of Cape Point at a point on the beach (35° 13' 26" N - 75° 31' 39" W) and extends in a clockwise direction, one-half mile from Cape Point, to a point on the beach (35° 13' 23" N - 75° 31' 59" W) northwest of Cape Point.

(2) Atlantic Ocean - Onslow and Pender Counties. Commercial fishing gear may not be used during the time specified for the following areas:

A) Topsail Beach. From January 1 through December 31, that area around Jolly Rodger Fishing Pier bordered on the offshore side by a line 750 feet from the end of the pier and on the northeast and southwest by a line beginning at a point on the beach one-quarter mile from the pier extending seaward to intersect the offshore boundary.

(B) Surf City:

(i) From January 1 to June 30, those areas around the Surf City and Barnacle Bill's Fishing Piers bordered on the offshore side by a line 750 feet from the ends of the piers, on the southwest by a line beginning at a point on the beach one-quarter mile from the piers and on the northeast by a line beginning at a point on the beach 750 feet from the piers extending seaward to intersect the offshore boundaries.

(ii) From July 1 to December 31, those areas around the piers bordered on the offshore side by a line 750 feet from the ends of the piers, on the southwest by a line beginning at a point on the beach 750 feet from the piers and on the northeast by a line beginning at a point on the beach one-quarter mile from the piers extending seaward to intersect the offshore boundaries.

(3) Atlantic Ocean - New Hanover County. Carolina Beach Inlet through Kure Beach. Commercial fishing gear may not be used during the times specified for the following areas:

(A) From the Friday before Easter to November 30, within the zones adjacent to the Carolina Beach, Center and Kure Beach Fishing Piers bordered on the offshore side by a line 750 feet from the ends of the piers and on the north and south by a line beginning at a point on the beach one-quarter mile from the pier extending seaward to intersect the offshore boundary, except the southern boundary for Kure Beach Pier is a line beginning on the beach one mile south of the pier to the offshore boundary for the pier.

(B) From May 1 to November 30, within 900 feet of the beach, from Carolina Beach Inlet to the southern end of Kure Beach with the following exceptions:

(i) From one-quarter mile north of Carolina Beach Fishing pier to Carolina Beach Inlet from October 1 to November 30:

(I) Strike nets may be used within 900 feet of the beach;

(II) Attended nets may be used between 900 feet and one-quarter mile of the beach.

(ii) Strike nets and attended gill nets may be used within 900 feet of the beach from October 1 to November 30 in other areas except those described in Part (a)(3)(A) and Subpart (a)(3)(B)(i) of this Rule.

(iii) It is unlawful to use commercial fishing gear within 900 feet of the beach from Carolina Beach Inlet to New Inlet from October 15 through October 17.

(b) It is unlawful to use gill nets or seines in the following areas during dates and

times specified for the identified areas:

(1) Neuse River and South River, Carteret County. No more than 1,200 feet of gill net(s) having a stretched mesh of five inches or larger may be used:
  (A) Within one-half mile of the shore from Winthrop Point at Adams Creek to Channel Marker "2" at the mouth of Turnagain Bay.
  (B) Within South River.

(2) Cape Lookout, Carteret County:
  (A) Gill nets or seines may not be used in the Atlantic Ocean within 300 feet of the Rock Jetty (at Cape Lookout between Power Squadron Spit and Cape Point).
  (B) Seines may not be used within one-half mile of the shore from Power Squadron Spit south to Cape Point and northward to Cape Lookout Lighthouse including the area inside the "hook" south of a line from the COLREGS Demarcation Line across Bardens Inlet to the eastern end of Shackleford Banks and then to the northern tip of Power Squadron Spit from 12:01 a.m. Saturdays until 12:01 a.m. Mondays from May 1 through November 30.

(3) State Parks/Recreation Areas:
  (A) Gill nets or seines may not be used in the Atlantic Ocean within one-quarter mile of the shore at Fort Macon State Park, Carteret County.
  (B) Gill nets or seines may not be used in the Atlantic Ocean within one-quarter mile of the shore at Hammocks Beach State Park, Onslow County, from May 1 through October 1, except strike nets and attended gill nets may be used beginning August 15.
  (C) Gill nets or seines may not be used within the boat basin and marked entrance channel at Carolina Beach State Park, New Hanover County.

(4) Mooring Facilities/Marinas. Gill nets or seines may not be used from May 1 through November 30 within:
  (A) One-quarter mile of the shore from the east boundary fence to the west boundary fence at U.S. Coast Guard Base Fort Macon at Beaufort Inlet, Carteret County;
  (B) Canals within Pine Knoll Shores, Carteret County;
  (C) Spooners Creek entrance channel and marina on Bogue Sound, Carteret County; and
  (D) Harbor Village Marina on Topsail Sound, Pender County.

(5) Masonboro Inlet. Gill nets and seines may not be used:
  (A) Within 300 feet of either rock jetty; and
  (B) Within the area beginning 300 feet from the offshore end of the jetties to the Intracoastal Waterway including all the waters of the inlet proper and all the waters of Shinn Creek.

(6) Atlantic Ocean Fishing Piers. At a minimum, gill nets and seines may not be used within 300 feet of ocean fishing piers when open to the public. If a larger closed area has been delineated by the placement of buoys or beach markers as authorized by G.S. 113-185(a), it is unlawful to fish from vessels or with nets within the larger marked zone.

(7) Topsail Beach, Pender County. It is unlawful to use gill nets and seines from 4:00 p.m. Friday until 6:00 a.m. the following Monday in the three finger canals on the south end of Topsail Beach.

(8) Mad Inlet to Tubbs Inlet – Atlantic Ocean, Brunswick County. It is unlawful to use gill nets and seines from September 1 through November 15, except that a maximum of four commercial gill nets per vessel not to exceed 200 yards in

length individually or 800 yards in combination may be used.

History Note: Authority G.S. 113-133; 113-134; 113-182; 113-221; 143B-289.52; Eff. March 1, 1996.

SUBCHAPTER 03M – FINFISH

SECTION .0100 – FINFISH, GENERAL

.0103 MINIMUM SIZE LIMITS

It shall be unlawful to possess, sell, or purchase fish under four inches in length except:

(1) for use as bait in the crab pot fishery in North Carolina with the following provision: such crab pot bait shall not be transported west of U.S. Interstate 95 and when transported, shall be accompanied by documentation showing the name and address of the shipper, the name and address of the consignee, and the total weight of the shipment.

(2) for use as bait in the finfish fishery with the following provisions:

(a) It shall be unlawful to possess more than 200 pounds of live fish or 100 pounds of dead fish.

(b) Such finfish bait may not be transported outside the State of North Carolina.

Bait dealers who possess valid finfish dealers license from the Division of Marine Fisheries are exempt from Subitems (2)(a) and (b) of this Rule. Tolerance of not more than five percent shall be allowed. Menhaden, herring, gizzard shad, pinfish and live fish in aquaria other than those for which a minimum size exists are exempt from this Rule.

History Note: Authority G.S. 113-134; 113-185; 143B-289.52; Eff. July 1, 1993.

SECTION .0500 – OTHER FINFISH

.0502 MULLET

The Fisheries Director may, by proclamation, impose any or all of the following restrictions on the taking of mullet:

(1) Specify season,

(2) Specify areas,

(3) Specify quantity,

(4) Specify means/methods,

(5) Specify size.

History Note: Authority G.S. 113-134; 113-182; 113-221; 143B-289.52; Eff. January 1, 1991.

5. STATUS OF STOCK

5.1 GENERAL LIFE HISTORY

Glossary of Biological Terms

A glossary of biological terms can be found in the Appendix 1.

Background

Striped mullet (*Mugil cephalus*) occur worldwide, predominantly in sub-tropical to tropical latitudes (Collins 1985a). Along the western Atlantic, striped mullet have been documented from Nova Scotia to Brazil, although stages older than young-of-the-year (YOY) are not commonly reported into the Middle Atlantic Bight (Able and Fahay 1998). The striped mullet is also known as the jumping mullet, black mullet, grey mullet, popeye mullet, whirligig mullet, common mullet, molly, callifavor, menille, liza, and lisa (Ibanez-Aguirre et al. 1995; Leard et al. 1995).

The striped mullet, white mullet (*Mugil curema*), and mountain mullet (*Agonostomus monitcola*) are the three Mugilid species found in North Carolina. Striped mullet and white mullet are similar in appearance, but can be taxonomically distinguished by anal fin ray counts or pectoral fin measurements (Collins 1985a; Collins 1985b). Striped mullet possess 11 anal fin elements: 3 anal spines and 8 anal fin rays, and the pectoral fins are 66 to 74% of the head length; white mullet possess 12 anal fin elements: 3 anal spines and 9 anal fin rays, and the pectoral fin lengths are 77 to 84% of the head length (Collins 1985a; Collins 1985b). Striped mullet also develop longitudinal stripes along the body by its juvenile stage. White mullet lack stripes and possess a distinct gold spot on the opercle (gill cover). Juvenile white mullet are commonly found during summer months in estuarine habitats shared by striped mullet (Martin and Drewry 1978; DMF unpublished data). In North Carolina, white mullet demonstrate a seaward emigration during the fall months, presumably migrating to Florida or southwards (Collins 1985b). Reproductive activity of white mullet in North Carolina waters is not documented. White mullet older than age 1+ are rarely collected north of Florida (Anderson 1958). One specimen of mountain mullet was noted in Brunswick County, North Carolina (Rohde 1976).

All body lengths (standard length (SL), fork length (FL), or total length (TL)) cited from scientific literature are reported as TL in this section (Figure 5.1).

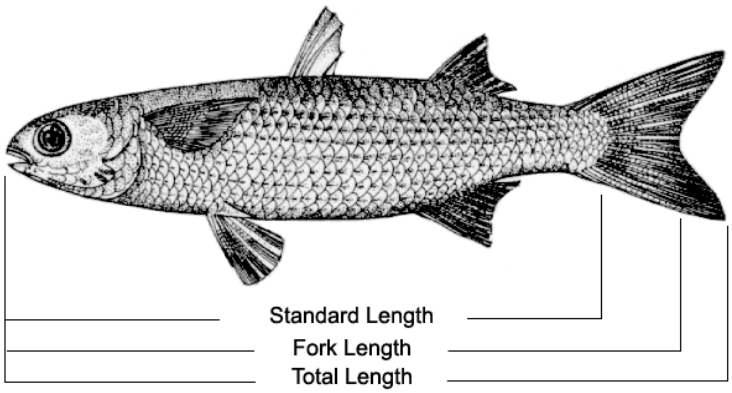

Figure 5.1. Common measurements of fish length; standard length, fork length, and total length.

Physio-chemical Tolerances and Preferences

Temperature

In a generalized summary of its worldwide distribution, Collins (1985a) suggested that striped mullet are not permanent residents in waters with temperatures below 16° C, or where waters fail to reach 18°. However, minimum temperatures are otherwise reported between 4.5 to 9.0° C (Martin and Drewry 1978). Overwintering striped mullet were observed at less than 2° C in low salinity habitats (< 2 ppt) in North Carolina (DMF unpublished data). Juveniles were observed (in poor condition) at water temperatures as high as 41° C in concrete culvert pools in Hawaii (Major 1977). In the laboratory, smaller striped mullet (< 50 mm) generally preferred higher water temperatures, 30.0 to 32.4° C, than larger fish, 19.5 to 29.0° C (Major 1977; Collins 1985a). Peak growth of juveniles of mixed *Mugil* spp. (striped mullet and white mullet) occurred at greater than 25° C in laboratory experiments (Peterson et al. 2000).

Salinity

The striped mullet is a trademark euryhaline species (Collins 1985a; Hotos and Vlahos 1998). Field specimens have been collected in salinities ranging from 0 to > 80 ppt (Martin and Drewry 1978). Young-of-the-year (YOY) striped mullet are capable of full osmoregulation and can tolerate freshwater to full seawater salinities by 40 mm (Nordlie et al. 1982). Specimens as small as 30 mm have been observed in freshwater creeks in North Carolina (DMF unpublished data). In the laboratory, no significant mortality occurred in YOY from abrupt salinity changes of 20 ppt to > 40 ppt (Hotos and Vlahos 1998). Furthermore, YOY acclimated to a maximum salinity of 126 ppt before behavioral and physical signs of stress and mortality occurred in the laboratory (Hotos and Vlahos 1998). Peak growth of juveniles of mixed *Mugil* spp. (striped mullet and white mullet) occurred at 17 ppt among three water temperatures in laboratory experiments (Peterson et al. 2000).

Food/ Feeding

The striped mullet is recognized as an important ecological bridge between a wide range of trophic levels. It directly connects base food chain items such as detritus and diatomaceous

microalgae, phytoplankton and zooplankton, and marine snow (Odum 1968; Moore 1974; Collins 1985a; Larson and Shanks 1996; Torras et al. 2000), with top-level predators, such as birds and fishes, sharks, and bottlenose dolphins (Breuer 1957; Thomson 1963; Collins 1985a; Barros and Odell 1995; Fertl and Wilson 1997). Carnivorous feeding (on copepods, mosquito larvae, and microcrustaceans) is common in striped mullet larvae and small juveniles (Harrington and Harrington 1961; DeSilva 1980), followed by a stronger dependence on benthic (bottom) detritus and sediment with increasing body size (DeSilva and Wijeyaratne 1977).

Adult striped mullet are well-documented herbivorous detrivores (Odum 1970; Collins 1985a). Adults are commonly described as 'interface feeders' (feed on water surface, water bottom, or surface of objects). Adults consume epiphytic (attached to the surface of a plant) and benthic microalgae (*viz*. unicellular green algae, filamentous blue-green algae, diatoms), bacteria, Protozoa, and other microorganisms associated with the top layers of fine sediments, detritus, and submerged surfaces such as rocks, eelgrass (*Zostera marina*) and turtle grass (*Thalassia sp.*) blades (Odum 1970; Moore 1974). Adults also feed on surface water 'scum' composed of accumulations of microalgae (Odum 1970). Ingested sediment particles are known to function as a grinding substrate in the degradation of plant cell walls in a gizzard-like pyloric stomach of the striped mullet (Thomson 1966). Anecdotal reports of feeding behaviors on mid-water polychaetes, *Nereis succinea*, and live bait of anglers also indicate opportunistic, carnivorous feeding by adults in non-interface areas (Bishop and Miglarese 1978). Collins (1981) reported that feeding activity was restricted to daylight hours.

Reproductive Biology

Size at Maturity

Striped mullet are iteroparous, isochronal, spawners (spawn many times over a lifetime, in one batch per year) (Thomson 1966; Sulochanamma et al. 1981; Greeley et al. 1987; Render et al. 1995; Bichy 2000). Striped mullet generally reach maturity between 248 to 373mm (9.7 - 14.7 in.), with females maturing at a slightly larger size than males (Collins 1985a). Female size at first maturity ranged between 285 to 335 mm (11.2 – 13.2 in.) in Florida, with smaller fish attaining maturity later in the spawning season (Greeley et al. 1987). In a study in Georgia, male and female striped mullet developed gonads beginning at 287 and 307 mm [11.3 and 12.1 in. (Pafford 1983)]. The smallest male and female specimens in Georgia reaching peak gonad maturation occurred at 320 and 327mm [12.6 and 12.9 in. (Pafford 1983)]. In South Carolina, males began to exhibit spermatogenesis between 225 and 250 mm (8.9 and 9.8 in.) and females exhibited oogenesis between 275 and 300 mm [10.8 and11.8 in. (McDonough 2001)]. In a North Carolina study, the smallest, mature, male and female, specimens were 335 and 374mm [13.2 and 14.7 in. (Bichy 2000)]. Lengths where 50% of the male and female fish were mature (L50%) were 317 and 374 mm [12.5 and 14.7 in. (Bichy 2000)]. Smaller North Carolina females also tended to spawn later in the season (Bichy 2000).

Age at Maturity

Most reports summarize the age at maturity as age 2, although a large amount of individual variation is reported (Thomson 1966; Moore 1973; Moore 1974; Martin and Drewry 1978; Pafford 1983). More recent works indicate that maturity often occurs earlier than age 2 (Collins 1985a; Bichy 2000). In North Carolina, over 75% of both males and females were mature at age 1 (Bichy 2000). No North Carolina females were mature at age 0, while 36% of age 0 males were mature (Bichy 2000).

Sex ratio

Earlier male maturation appears to be a common trait of the striped mullet (Pafford 1983; Bichy 2000). Studies clearly reveal a progression from male to female dominated sex ratio with increasing body length (Silva and De Silva 1981; Mahmoudi et al. 1990; Bichy 2000; McDonough 2001; DMF unpublished data). Mahmoudi et al. (1990) suggest that striped mullet first develop as males, followed by sexual differentiation into females with the development of oogonia and oocytes. There are also reports of rare occurrences of hermaphroditic striped mullet specimens, however they are considered atypical (Moe 1966; Franks et al. 1998).

Fecundity

Fecundity measures from a wide assemblage of studies range from 220,000 to 7.2 million eggs per individual; with fecundity positively related to body size (Appendix 1, Table 1) (Broadhead 1953; Thomson 1963; Martin and Drewry 1978; Silva and De Silva 1981; Pafford 1983; Greeley et al. 1987; Bichy 2000; Wenner 2001). Recent studies have reported maximum fecundity around 1.5 to 4 million eggs per female (Whitfield and Blaber 1978; Pafford 1983; Render et al. 1995; Bichy 2000; Wenner 2001; Bichy and Taylor 2002).

Reported estimates of relative fecundity have ranged between 648 to 2,616 eggs/ g of body weight (Shehadeh et al. 1973; Nash et al. 1974; Render et al. 1995; Bichy 2000).

Spawning Location

The striped mullet is often considered a catadromous species due to its predictable migrations from freshwater habitats into marine spawning areas (Martin and Drewry 1978; Collins 1985a; Blaber 1987). The concentrated abundance of eggs and larvae in offshore collections support offshore waters as spawning grounds (Broadhead 1953; Anderson 1958; Arnold and Thompson 1958; Finucane et al. 1978; Martin and Drewry 1978; Powles 1981; Ditty and Shaw 1996; Able and Fahay 1998). Anecdotal, offshore observations of spawning behaviors and large, seaward migrations of spawning adults also indicate offshore spawning (Jacot 1920; Arnold and Thompson 1958). However, in addition to offshore waters, spawning likely also occurs in nearshore coastal waters, lower estuarine areas and sounds (albeit less frequently), and perhaps in freshwater in extremely rare circumstances (Jacot 1920; Breder 1940; Johnson and McClendon 1969; Shireman 1975; Martin and Drewry 1978; Collins and Stender 1989; Bettaso and Young 1999). A near-shore ocean specimen with hydrated oocytes was found only 100 to 200 m from shore off Hatteras, North Carolina (Bichy 2000). Hydration occurs within 1 to 2 days before spawning (Martin and Drewry 1978). Observations suggest that spawning occurs at night, near the surface (Anderson 1958; Arnold and Thompson 1958). Larval abundance in Florida collections suggests that peak spawning occurs around new and full moon spring tides (Greeley et al. 1987).

Gonadosomatic Index and Spawning Period

Very high, mean, monthly, gonadosomatic index (GSI) values of 20 to 25% were displayed by striped mullet in South Carolina, Georgia, and Louisiana (Pafford 1983; Render et al. 1995; McDonough 2001; Wenner 2001). Gonadosomatic index is the ratio of ovary weight to total body weight, multiplied by 100. Gonadosomatic index values increased with female size, yet asymptoted at 357mm (14 in.) in Louisiana specimens (Render et al. 1995). The spawning period begins earlier in more northern latitudes, yet is otherwise very similar in duration and pattern in North Carolina, South Carolina, Georgia, and Louisiana. The spawning season in

North Carolina spans September to March, with peak spawning occurring in October and November (Jacot 1920; Bichy and Taylor 2002). North Carolina GSI values begin to rise rapidly in September (6%), peak in October (14%), remain high in November and December (~11%), diminish in January (4%), and decline to ~0% in April (Bichy and Taylor 2002). Although spawning may occur into March, limited microscopic examinations of gonads indicated that most gravid (egg carrying) females were re-absorbing atrectic (non-viable) oocytes after November. However, specimens with vitellogenic (viable) oocytes were noted into January (Bichy and Taylor 2002). In South Carolina and Georgia, GSI values indicated that spawning occurred from October through February, with a peak in November (Pafford 1983; McDonough 2001). Gonadosomatic Index values indicated peak spawning in December and January in Florida (Greeley et al. 1987). A very slight resurgence in GSI values roughly 3 months after the peak spawning period was noted in South Carolina, Georgia, and Louisiana (Pafford 1983; Render et al. 1995; McDonough 2001).

Age, Growth, and Development

Eggs

Spawning striped mullet broadcast transparent to straw-colored, buoyant, stenohaline (adapted to narrow salinity ranges) eggs (Kuo et al. 1973; Collins 1985a). Highest egg survival occurs between 28 to 33 ppt (Sylvester et al 1975). *In vitro* fertilization rate is 90%; *in vitro* hatching rate is 42% (Abraham et al. 1999). Fertilized egg diameters range between 0.60 to 0.98 mm (Martin and Drewry 1978; Kuo et al. 1973; Collins 1985a; Abraham 1999). Individual, fertilized, eggs contain a single oil globule, ranging between 0.26 to 0.40 mm in diameter (Martin and Drewry 1978; Kuo et al. 1973; Collins 1985a). Optimum egg development occurs within the range of 21 to 24°C (Sylvester et al. 1975). Hatching occurs 36 to 38 h after fertilization at 24°C, and 48 to 50 h at 22°C (Kuo et al. 1973).

Yolk Sac Larvae

Larvae average 2.65 mm at hatching (Pattillo et al. 1999) and range between 2.2 to 3.6 mm (Martin and Drewry 1978). Larvae hatch with no mouth, paired fins, or branchial skeleton (Thomson 1963). A yolk sac with an ovoid to oblong-ellipsoidal oil globule is present on larvae for 2 to 5 days at 26°C (Martin and Drewry 1978). Typically, by 4 days, the mouth is formed, pectoral fins are developing, gill clefts have opened, and the yolk has been absorbed, although the oil globule is still present (Martin and Drewry 1978). Kuo et al. (1973) found little effect of temperature on yolk sac absorption rate; however, oil globule content persisted longer at lower temperatures. Steep growth occurs from yolk nutrition on day one, however, little to no growth occurs during the remainder of the yolk sac stage (4-5 d) (Kuo et al. 1973; Martin and Drewry 1978). Over 90% of larval mortality in the laboratory occurred during the initial 10 days of larval life (Martin and Drewry 1978; Kuo et al. 1973).

Larval Stage

Substantial growth occurs with the onset of feeding, beginning on the 5^{th} to 8^{th} day post-hatch, followed by an intensification in feeding between the 9^{th} to 12^{th} day (Kuo et al. 1973; Martin and Drewry 1978). Stomach, spleen, intestines, gall bladder, and swim bladder begin forming between 3.1 to 3.4 mm on approximately the 5^{th} day (Martin and Drewry 1978). Gill filaments begin to form at 3.4 to 3.8 mm at 8 d (Martin and Drewry 1978). Complete oil globule depletion occurs by 10 d at 24°C and 15 d at 22°C (Kuo et al. 1973). Gill lamellae are present at 3.85 to 5.7 mm at 14 to 15 d (Martin and Drewry 1978). Heavy pigmentation is scattered

over the body by 5.4 to 6.6 mm, with a silver-white or silver-green color developing ventrally from the gill cover to anus (Martin and Drewry 1978). Eleven anal fin rays are present at 6 mm (Martin and Drewry 1978; Ditty and Shaw 1996), which is an important diagnostic tool for separating *M. cephalus* and *M. curema* (Collins 1985a). Scales begin to develop at 8 to 10 mm (Martin and Drewry 1978). Striped mullet are approximately 11 mm at the end of the larval stage (24 to 28 d) (Martin and Drewry 1978).

Pre-juveniles

*Some referenced body lengths for pre-juveniles and juveniles were not converted to total lengths because of the declining relationship between SL and TL for very small sizes during these early life history stages.

Martin and Drewry (1978) recognize a pre-juvenile stage from 11 to 52 mm TL, with an approximate age of 30 to 90 days at its conclusion (Thomson 1966). The pre-juvenile stage is also referred to as the querimana stage (Thomson 1966). The 11 anal fin rays fuse into a complement of 2 anal spines and 9 anal fin rays at 19 to 23 mm TL (Collins 1985a). The diagnostic count of 3 anal spines and 8 anal fin rays is evident at 35 to 45 mm SL (Anderson 1958). Scales are absent on the second dorsal and anal fins, unlike white mullet (Able and Fahay 1998). Pre-juveniles between 16 to 40 mm TL are brilliant silver ventrally and laterally, progressively more pigmented, tan, and brown on its dorsal surface (Martin and Drewry 1978; Able and Fahay 1998). Stripes become evident after 40 mm SL (Martin and Drewry 1978). The adipose eyelid is microscopically noticeable at 28 mm TL; macroscopically (visibly) noticeable by 42 mm TL (Martin and Drewry 1978).

Juveniles

The juvenile stage encompasses a size range from 52 to 248 mm TL (Martin and Drewry 1978). Gill rakers increase from approximately 32 at 59 mm SL, to 48 at 117 mm SL (Martin and Drewry 1978). Juveniles and adults possess the same complement of fins (Martin and Drewry 1978). Striped mullet reach 50 mm TL by 5 months (by their first March-May) (Futch 1966). Higgins (1927) observed the arrival of YOY (22 mm “body length”) at Beaufort, North Carolina by mid January, noted little growth until water temperatures reached 20 ° C in mid April, and estimated approximately 20 mm of growth per month from May to October. Anderson (1958) estimated 5 mm growth per month for Georgia YOY (~18 to 19 mm SL) from November until January, followed by no growth during the coldest winter months. About 10 mm growth occurred between February and March during rising water temperatures, followed by a growth rate of 17 mm per month to next October (Anderson 1958). Anderson (1958) suggested that the greater period of delayed YOY growth observed by Higgins in North Carolina was due the more extended winter season.

Two year-classes, separated by several months, were observed in North Carolina and Georgia (Jacot 1920; Higgins 1927; Anderson 1958). Anderson (1958) determined that by their second winter in Georgia, juveniles would fall into two average size groups, 197 mm and 122 mm TL, depending on the timing of its spawning.

First annulus formation occurs at approximately 13 to 18 months, followed by successive annuli formations between April and August (Thompson et al. 1989; Thompson et al. 1991; Virgona et al. 1998; McDonough 2001). Marginal increment analyses show that annulus formation occurs from May to June in North Carolina, South Carolina, and Georgia (Foster 2001; McDonough 2001; NCDMF 2001a). Size at first annulus formation ranges from 120 to

200 mm FL [Leard et al. 1995 (Appendix1, Table 2)]. Lengths at annuli formations were varied among studies that used both scales and otoliths for aging [Leard et al. 1995 (Appendix 1, Table 2)].

Adults

Adults grow at a rate of 38 to 64 mm per year (Broadhead 1953; NCDMF 2001b). Spring and summer growth is twice as fast as fall and winter growth (Broadhead 1953; Rivas 1980). Adults grew 7 mm in each of the first and fourth quarters of the year, and averaged 16 and 19 mm growth in the second and third quarters of the year in a Florida tagging study (Broadhead 1958).

Otolith growth is closely related to body growth for fishes (Helfman et al. 1997). Incremental otolith growth in striped mullet occurs primarily from July to November in Louisiana (Thompson et al. 1991) and June to October in North Carolina (NCDMF 2001a). Thompson et al. (1991) indicated that energy required for somatic growth was reallocated for reproduction and post-spawning recovery (during the fall and winter, November - March). Summer growth depression in striped mullet (age 1+) was observed in Texas, associated with prolonged elevation of water temperatures and potential shifts in food types (Moore 1973; Cech et al. 1975). A similar cessation in marginal incremental growth in otoliths was observed for older striped mullet in August and September in North Carolina (NCDMF 2001a).

Males and females are at similar lengths at early ages (< age 2), after which, females grow larger and live longer [Table 5.1 (Mamhoudi et al. 1990; DMF unpublished data)]. Large variability in size at early ages is seen in North Carolina, South Carolina, and Georgia stocks (Foster 2001; McDonough 2001;NCDMF 2001a). North Carolina striped mullet appear to achieve larger mean lengths at earlier ages than more southern U.S. states (Bichy 2000; NCDMF 2001a). For example, mean length for age 1 striped mullet (both sexes) in South Carolina was 257 mm, substantially smaller than males and females (317, 346 mm) in North Carolina (McDonough 2001; DMF unpublished data). On average, age 2 males and females in South Carolina were 310 mm compared to 344 mm and 394 mm in North Carolina (McDonough 2001; DMF unpublished data). Since birth date is standardized as January 1 for aging convention along the U.S. east coast, earlier spawning times and true birth dates in North Carolina may contribute to slightly larger mean lengths at young ages.

Table 5.1. Average length at age for North Carolina male and female striped mullet. TL = total length; n= number of specimens.

Males				Females			
Age	TL (mm)	TL (inches)	n	Age	TL (mm)	TL (inches)	n
0	220	8.7	196	0	220	8.7	196
1	317	12.5	342	1	346	13.6	263
2	344	13.5	489	2	394	15.5	978
3	379	14.9	61	3	441	17.4	486
4	446	17.6	9	4	483	19.0	181
5	428	16.8	6	5	506	19.9	66
7	518	20.4	1	6	518	20.4	45
				7	586	23.1	7
				8	652	25.7	1
				10	593	23.4	3
				11	410	16.1	1

Length-Weight Relationship

The length (L) – weight (W) relationship found in North Carolina striped mullet was expressed as ln (W) = -17.87 + 2.968 * ln (L) (NCDMF 2001a). Leard et al. (1995) summarized the relationships between length and weight for various studies (Appendix 1, Table 3).

Maximum Age and Maximum Size

Maximum age for striped mullet is reported as 13 years (Thomson 1963). Male and female maximum ages of 7 and 11 were recorded in North Carolina research (Table 5.1). Maximum reported sizes ranged from 791 mm in North Carolina to a 914 mm specimen from India (Gopalakrishnan 1971; DMF unpublished data).

Movements and Migrations

Larval Transport and Migration

Striped mullet larvae are found during the winter and spring months over a range of offshore depths (9 to 914 m) in the South Atlantic Bight [SAB (Collins and Stender 1989)]. The greatest abundances of larvae occurred at <25°C (mean=23°C) and >34 ppt in the Gulf of Mexico (Ditty and Shaw 1996), and along the 180 m contour off the SAB (Powles 1981). Larval size is negatively related to distance from shore, indicating an inshore migration with growth (Powles 1981; Collins and Stender 1989). Larvae exhibit a strong association with surface waters and show no indication of diel vertical migration (Powles 1981; Collins and Stender 1989). The shoreward migration in the SAB is likely facilitated by onshore, wind-driven, (Ekman) drift, characteristic of southeast U.S. winter wind patterns (Powles 1981).

Young-of-the-year and Juvenile Movement

Larval and YOY striped mullet are absent in offshore waters by April in the Gulf of Mexico and by early March in the SAB (Anderson 1958; Ditty and Shaw 1996). Pre-juvenile striped mullet are 20 to 25 mm when they appear on outer beaches, reported as early as November in Georgia (Gunter 1945; Anderson 1958; Ditty and Shaw 1996). Pre-juveniles enter estuarine areas in January in North Carolina, at 22 mm (Higgins 1927). YOY overwinter in estuarine marsh areas and apparently scatter among ranging habitat types during summer and fall (Anderson 1958). Collins (1985a) noted that YOY and juveniles move into deeper waters with the adult migration in the fall.

Adult Movement and Migrations

Martin and Drewry (1978) report that adults occupy shallow waters during a 'trophic' (feeding) phase from spring to summer/early fall between migration (spawning) periods. Adults generally do not move extensively during this trophic period (Leard et al. 1995).

Most adult movement occurs during a pronounced spawning migration that occurs in fall and winter months in the southeast U.S. and Gulf of Mexico (Leard et al. 1995; Collins 1985a; Bichy 2000). Onset of migration is marked by increased schooling aggregation and downstream movement towards marine waters (Jacot 1920; Martin and Drewry 1978). Increased migratory movements have been associated with north/northwest winds and cold fronts (Jacot 1920; Apekin and Vilenskaya 1979; Mahmoudi et al. 1990; DMF unpublished data). Hurricanes and unseasonably warm fall water temperatures may delay or disrupt spawning migrations (Thompson et al. 1991). Patterns of movements unrelated to spawning are otherwise difficult to generalize, as all age groups can be found from freshwater to lower estuarine waters at all times of the year (Thomson 1955).

Tagging Studies

Most tagging studies show limited distances between tagging and recapture locations for adults (Idyll and Sutton 1951; Broadhead and Mefford 1956; Collins 1985a; Mahmoudi et al. 2001; McDonough 2001; NCDMF 2001b). Ninety percent of recaptures occurred within 32 km of the tagging location in Florida (Idyll and Sutton 1951; Broadhead and Mefford 1956), while 91% of recaptures were found within 83 km of the release site in North Carolina (NCDMF 2001b).

Most of the movements observed in tagging studies are associated with the spawning migration. The spawning migration along the southeast U.S. coast occurs in a general southward direction (Jacot 1920; Broadhead and Mefford 1956; Martin and Drewry 1978; NCDMF 2001b). The vast majority of tagged fish that were recaptured during spring months (presumably after spawning) in North Carolina were found south of the original tagging location (NCDMF 2001b). No reciprocal, northward, adult migration is observed (Jacot 1920). However, egg and larval transport occurs in a northward direction with the Florida current (Gulf stream) along the southeast U.S. (Able and Fahay 1998).

The overall direction of recapture in tagging studies in North Carolina and South Carolina was to the south (McDonough 2001; NCDMF 2001b). Almost every out-of-state recapture was found in more southern states (McDonough 2001; NCDMF 2001b). Low percentages of out-of-state recaptures in North Carolina and South Carolina (1.8 and 9%) may suggest that striped mullet stocks are fairly residential to native states (McDonough 2001;

NCDMF 2001b). Mahmoudi et al. (2001) noted that the majority of adults in Florida were recaptured in the same system in which they were tagged.

5.2 STOCK STATUS

A population assessment of the North Carolina striped mullet (*Mugil cephalus*) stock (Attachment 1) was conducted by means of a statistical catch-at-age-analysis based on the stock synthesis approach by Methot (1990; 2000). This population model is an age- and size-based forward projection analysis, incorporating a wide collection of fishery-dependent and -independent data. Age-specific estimates of population abundance and commercial and recreational fishing mortalities for each half-year period covering a nine-year time series (1994-2002) were produced in the population model for separate male and female populations. Benchmark fishing mortality rates proposed as thresholds for sustainability, were calculated using life history and fishery information unique to the North Carolina striped mullet stock. Observed fishing mortality estimates from the population model were evaluated in relation to the fishing mortality thresholds, to determine if overfishing is occurring on the stock.

Striped mullet inhabiting North Carolina coastal and joint waters comprise the unit stock in the assessment. The North Carolina striped mullet stock falls under the jurisdiction of the North Carolina Marine Fisheries Commission and the North Carolina Wildlife Resources Commission. The North Carolina Division of Marine Fisheries (DMF) directly manages the stock under these two regulatory commissions. No inter-state management over the Atlantic coastal striped mullet population is in effect.

The North Carolina striped mullet commercial fishery is the largest along the U.S. Atlantic seaboard, averaging 2.18 million pounds from 1994 to 2002. The commercial fishery is predominantly a fall, roe targeting, gill net fishery. Rapid surges in roe value in the late 1980s, followed by rising commercial fishing effort and landings through the mid 1990s caused concern for the North Carolina stock. The stock has been officially recognized as a species of concern by the State of North Carolina since 1999.

Recreational landings in North Carolina are smaller than commercial landings, and are composed of two types of harvest: cast netted juveniles used for hook and line bait, and recreationally gill netted striped mullet. Annual recreational bait harvest in North Carolina consists of approximately 350,000 striped mullet (DMF unpublished data). The DMF estimated that 66,205 striped mullet (equivalent to 64,213 lb) were recreationally harvested by small mesh gill nets in 2002. Recreational gill net landings are harvested by Recreational-Commercial Gear License (RCGL) holders.

Data Sources

Life history data sources utilized in the assessment included two sources of age-growth data, a length-weight relationship, length-based maturity curve for females, length-based sex-ratio information, and an age-specific natural mortality model. Fishery landings and age compositions from the recreational and commercial sectors were included in the population model. RCGL harvest was included in the commercial fishery landings, given the similarity in capture gears (i.e. small mesh gill nets). It was necessary to view RCGL landings with commercial landings due to the lack of RCGL size (or age) information. Recreational landings in the assessment, therefore, consisted only of bait harvest. Commercial fishery gill net catch-per-unit-effort (CPUE) and four DMF fishery-independent surveys provided information about year-to-year stock abundance. Of the four DMF fishery-independent surveys, two gill net

surveys provided indices of adult CPUE and length compositions, and two seine surveys served as juvenile abundance indices (JAI).

Results

Based on the population model results, the three highest estimates of age 0 recruitment (R_0) have occurred in the most recent five years, peaking in 2002. High yearly levels of R_0 are characteristic for the stock, averaging 61 million new recruits per year. Female spawning stock biomass (SSB) has increased from 1994 to 2002, with peak SSB occurring over the last three years of the assessment.

Fishing mortality (instantaneous rate, *F*) was estimated separately for the recreational and commercial fisheries, notated as F_r and F_c. Fishing mortality was also estimated for each January-June and July-December period, referred to as $F_{c\,Jan}$ and $F_{c\,Jul}$, as examples. Full year fishing mortality is the sum of the seasonal *F* rates within a year, written as $F_{r\,Tot}$ or $F_{c\,Tot}$.

Only minor recreational fishing mortality (F_r) is incurred on juveniles from recreational bait harvest. Recreational fishing mortality occurs almost exclusively on age 0 individuals from July to December. Essentially, the large numbers of striped mullet cast netted by anglers for bait is minimal in relation to the vast numbers of age 0 recruits that are produced each year.

Commercial *F* (F_c) is disproportionately higher on females than males and occurs with greater intensity in July-December than in January-June. On average, 66% of the $F_{c\,Tot}$ on males, and 91% of the $F_{c\,Tot}$ on females occurs in the July-December period. The commercial fishery also targets different age classes between the two seasons, as larger, older fish are sought in July-December. Full 100% selectivity (or full vulnerability) to the fishery occurs at age 2 in January-June, and at ages 3 and 4 for males and females in July-December. These age classes are considered 'fully-recruited' to the fishery. Fishing mortality on fully recruited age classes is hereby referred to as 'Full' *F*.

Full $F_{c\,Tot}$ on males has been stable from 1994-2002, averaging 0.80. Average commercial *F* on fully recruited females was 1.25. The heaviest exploitation on females and the largest fluctuations in $F_{c\,Tot}$ occurred in the early years (1994-1998) of the nine-year time series. The average full commercial fishing mortality on females over the last four years of the assessment (1999-2002) was $F_{c\,Tot}$ =1.09.

Overfishing Definitions

By definition, overfishing occurs when the fishing mortality rate exceeds the threshold *F* rate and the rate of removal of fish exceeds the ability of the stock to replenish itself (ASMFC 2004). Yield per recruit (YPR) and spawning stock biomass per recruit (SSB/R) modeling, and a replacement analysis of observed stock-recruitment data were used for defining *F*-based overfishing thresholds for the stock. The following benchmarks and thresholds are given as full year fishing mortality rates on fully recruited age classes.

F_{max} and $F_{0.1}$ were used as benchmarks to assess overfishing on males. $F_{0.1}$ is considered a conservative proxy for fishing at maximum sustainable yield (MSY) for some species. Overfishing is not occurring on males, considering recent fishing mortality rates (1999-2002 average Full $F_{c\,Tot}$ =0.71) in relation to $F_{0.1}$ =0.58 and F_{max} =1.65. It is likely that male abundance is adequate for overall stock sustainability, considering stable commercial *F* rates, increasing age 0 recruitment, and the generally reduced importance of males to reproduction

and sustainability.

The threshold *F* rate for females was based on a level of fishing that conserves 25% of the spawning stock biomass (SSB) compared to a condition where no fishing mortality occurs (*F* =0). This percentage of SSB is known as spawning potential ratio (SPR). This fishing threshold of $F_{25\%}$ =1.25 was considered a proxy for *F* at maximum sustainable yield (F_{msy}) for the stock. Adopting a threshold fishing mortality corresponding to SPR =25% was primarily based on rapid growth to maturity, large annual age 0 recruitment, and greater than 100 years of historical commercial landings similar in magnitude to the current fishery, ostensibly indicating a long-term self-sustaining stock at this level of exploitation. Replacement benchmarks F_{med} =1.37 and F_{low} =1.08 suggest that fishing at $F_{25\%}$ would result in sufficient recruitment to sustain current stock size.

Although the female stock is heavily exploited, overfishing is not occurring based on $F_{25\%}$ as the threshold fishing mortality rate. The 1994-2002 average commercial fishing mortality on females is Full $F_{c\,Tot}$ =1.25, with the 2000-2002 average =1.15. Terminal year (2002) Full $F_{c\,Tot}$ =1.11. The distinct pattern of very low commercial fishing mortality in January-June, combined with shifting fishery selectivity towards older fish in July-December, allows females to attain maturity before they face the full brunt of fishing mortality. Terminal stock abundance and age structure is most likely at sustainable levels, given the expanding SSB and high levels of R_0 estimates observed in the population model, and stable commercial *F* rates on females equivalent to 26-27% equilibrium spawning potential ratio of the stock over the most recent three years of the assessment. Although SSB and age structure likely maintain current harvest levels, reproduction comes heavily from younger age classes, requiring cautious management of the stock. A series of poor recruitment events could upset stock sustainability.

Given $F_{25\%}$ as a proxy for F_{msy}, the stock is currently fished near the maximum exploitation level that can maintain sustainability, thus leaving little room for acknowledged uncertainty in data used in the assessment or against unpredictable future events such as recruitment failures. The typical management response to dealing with uncertainty is to adopt more conservative thresholds that are considered precautionary (Haigh and Sinclair 2000). A target of $F_{30\%}$ =0.98 would be a option as a precautionary threshold for the stock.

6. STATUS OF FISHERIES

6.1 COMMERCIAL

6.1.1 History

The historic striped mullet fishery has a prominent role in the early development of the North Carolina commercial fishing industry. Smith (1907) ranked the striped mullet as the most abundant and important saltwater fish of North Carolina in the early 1900s. Its fishery importance is illustrated in the colloquial name of the Atlantic and North Carolina Railway, known as the 'Old Mullet Line', which connected coastal and piedmont North Carolina from the 1850's to 1950's (News-Carteret Times 2003). The striped mullet fishery operated at over 3 million pounds annually during the late 1800's (Chestnut and Davis 1975). The fishery was highly seasonal, occurring primarily during the fall spawning migration (Taylor 1951). Enormous catches of greater than 1 million pounds of mullet landings in a single day was not an uncommon event during these fall migrations (Smith 1907). These massive harvest pulses were larger than the market's distribution and holding capacity well into the 1950s (Taylor 1951). Fifty-eight percent of the harvest was salted in 1887 and 1888, while 76% of total harvest was salted during the period of 1889 to 1897 (Chestnut and Davis 1975). By the mid 1900's, 95% of the harvest was sold fresh, while the rest were brine-cured, salted, or filleted and packaged (Taylor 1951). Peak landings of over 6.7 million lb and 6.5 million lb were harvested in 1902 and 1936 [Chestnut and Davis 1975 (Figure 6.1)].

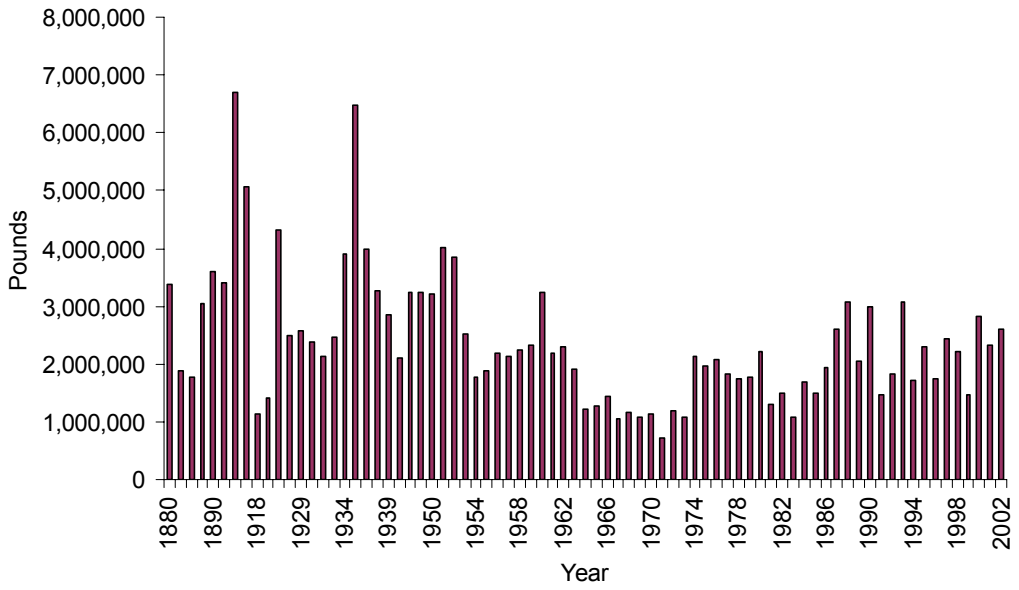

Figure 6.1. Historical landings of the North Carolina striped mullet fishery: 1880 – 2001. Landings data were not available for the following years: 1881-1886, 1891-1896, 1898-1901, 1903-1907, 1909-1917, 1919-1922, 1924-1926, 1933, 1935, 1941-1944, 1946-1948 (Division of Commercial Fisheries).

6.1.2 Collection of Commercial Statistics

Annual North Carolina landings data were collected by the Division of Commercial Fisheries (U.S. Fish and Wildlife Service, Department of the Interior) from 1880 to 1974 (Chestnut and Davis 1975). The National Marine Fisheries Service (NMFS) standardized the collection methods of landings statistics for U.S. south Atlantic fishery species in 1972. Landings were collected monthly from major seafood dealers, although reporting was not mandatory. North Carolina Division of Marine Fisheries (DMF) and NMFS began a cooperative commercial fishery data collection program in 1978, maintaining the same methodology established in 1972. However, DMF assumed the primary role of data collection for the State and further improved data collection coverage with additional staff. Under-reported landings, however, were a growing concern due to the program's reliance on voluntary cooperation from seafood dealers. The rising perception of deteriorating attitudes towards fisheries management by North Carolina fishermen in the late 1980s and early 1990s contributed to the reform of the DMF/NMFS cooperative statistics program (Lupton and Phalen 1996). With the support of the commercial fishing industry, DMF instituted a mandatory, dealer-based, trip-level, reporting system (known as the North Carolina Trip Ticket Program (NCTTP)) for all commercial species in 1994, which greatly improved reporting compliance. The number of dealers with reported mullet landings increased by 90% (115 to 218) between 1993 and 1994. Three hundred fifty-eight thousand pounds of mullet landings were contributed from these new dealers, which was 21% of the total landings for 1994. Improved collection methods beginning in 1994 should be considered when comparing pre-1994 landings with current landings.

6.1.3 Yearly Landings and Value

The North Carolina striped mullet fishery changed markedly in the late 1980s. From 1972 to 1986, annual landings in the mullet fishery averaged 1.66 million lb, with a range of 1.07 to 2.22 million lb (Figure 6.2). Average annual landings from 1987 to 1993 were 2.44 million lb, with landings near or exceeding 3 million lb in 1988, 1990, and 1993. Strong demand from Asia for striped mullet roe and competing roe-exporting companies combined to create a highly profitable roe fishery in North Carolina in 1988. In 1988, landings exceeded 3 million lb for the first time in 28 years.

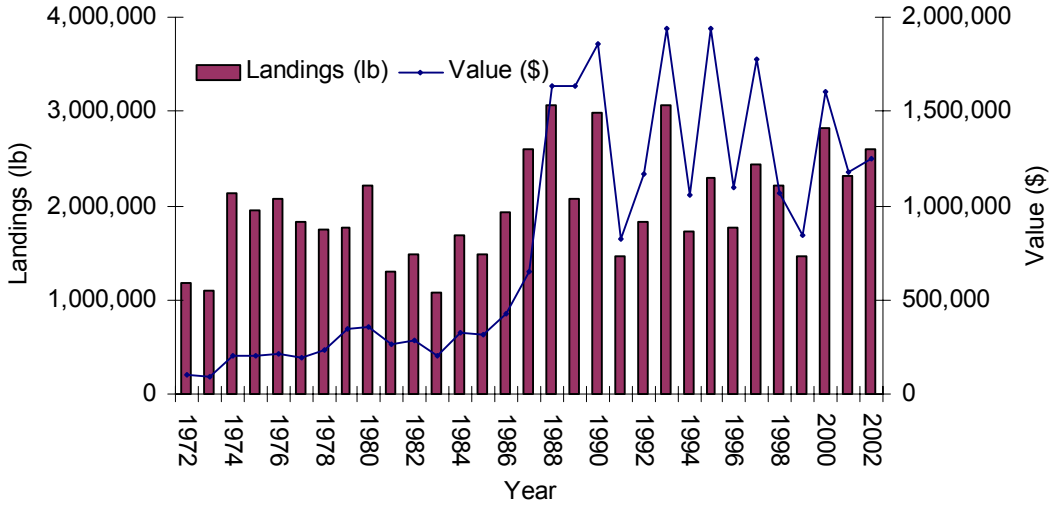

Figure 6.2 Striped mullet yearly landings and value from 1972 - 2002. Values ($) were not

adjusted for inflation

Value of the fishery increased even more conspicuously than landings during the late 1980s. From 1987 to 1988, landings increased by 18%, yet value grew by 150%. Average November price of striped mullet increased from $0.24 per lb (all market grades) in 1987 to $0.86 in 1988 and $1.35 in 1989 (Figure 6.3). In contrast, the market value of striped mullet was often lower during the peak spawning months (October and November) in previous years. Prices would often decline due to the surplus caused by the high availability of large, migratory, schools and little market demand. However, spawning female striped mullet graded as 'red roe' mullet were suddenly worth $1.00 – $1.80/lb in the late 1980s.

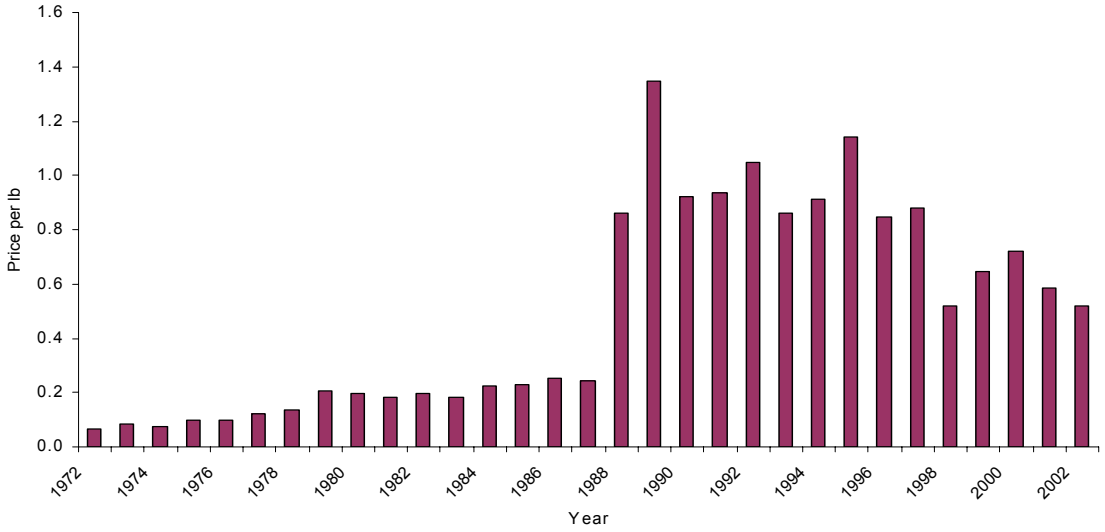

Figure 6.3. Average November price per lb for striped mullet (1972 - 2002). Averages include all market grades. Prices were not adjusted for inflation.

The average market price for striped mullet was minimal and generally stable throughout the year from 1972 to 1987 (Figure 6.4). The sudden market demand for roe in 1988 caused the average market price to explode during the main months (October - December) of the spawning season (Figure 6.4). Roe prices remained at a consistently high level until 1998. Market price for roe mullet declined in 1998 and has remained much lower than what was observed in 1988-1997. A depressed Asian economy in the late 1990s may have led to a decline in roe demand. In addition, the decline in market price was partially due to the fallout of some competing exporters, which created a more unified exporting industry.

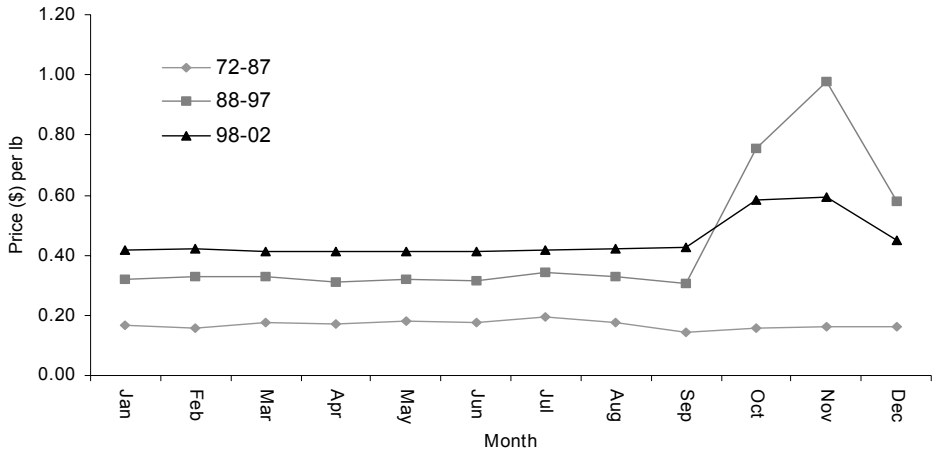

Figure 6.4. Average monthly price per lb of striped mullet for three distinct periods: 1972 - 1987; 1988 - 1997; 1998 - 2002. Averages include all market grades. Values are not adjusted to accommodate inflation.

6.1.4 Seasonal Harvest

The greatest intensity of harvest occurs in October and November, coinciding with the peak period of striped mullet spawning (Figure 6.5).

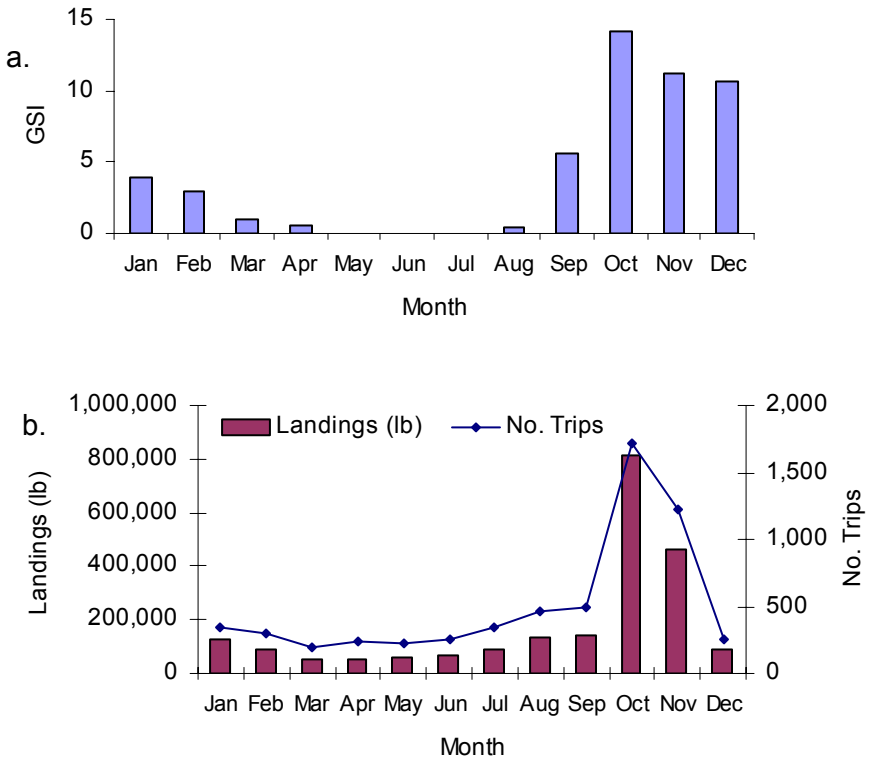

Figure 6.5 a. Average Monthly gonadosomatic index (GSI) values of striped mullet in NC from 1999-2001 9Bichy 2002). GSI is the ratio of gonad weight to body weight * 100. b. Average monthly landings and trips from 1994-2002 in the NC mullet fishery.

6.1.5 Primary Counties of Landings

Forty-four percent of the total harvest was landed in Carteret County from 1972-2002, over three times the next closest landings value were from Dare County (Table 6.1). The year-to-year proportion of total, statewide, landings taken by Carteret County has fluctuated widely between, 21% to 66%, since 1972 (Figure 6.6). Carteret County harvest share peaked in 1990 (66%) and has since declined. A decline in landings from the beach seine fishery, which occurs in Bogue Banks, is responsible for much of the reduced harvest in Carteret County. Dare County and Pamlico County harvests have increased over recent years (1994-2002) compared to the rest of the State (Figure 6.6). In 2002, steadily rising landings in Dare County essentially equaled landings in Carteret County (Figure 6.6).

Table 6.1. Average yearly landings (lb) of striped mullet by County: 1972 – 2002.

County	Average yearly landings (lbs)	Percent of total landings
Carteret	871,302	44%
Dare	247,284	12%
Onslow	171,118	9%
Pamlico	137,464	7%
Beaufort	93,135	5%
Brunswick	80,480	4%
Pender	79,965	4%
New Hanover	69,983	4%
Pasquotank	66,700	3%
Hyde	59,233	3%
Chowan	48,404	2%
Tyrrell	26,651	1%
Other	41,908	2%

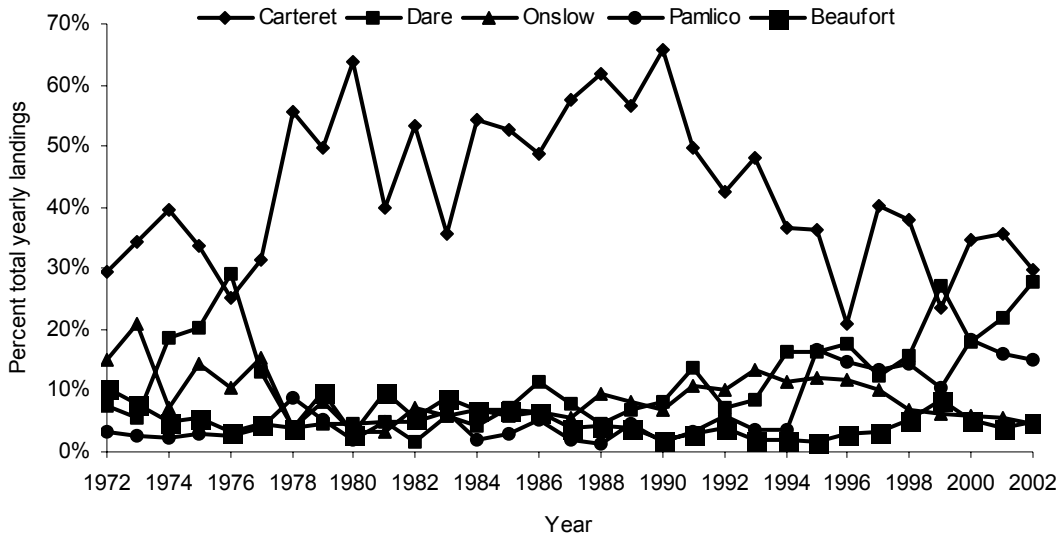

Figure 6.6. Yearly percentage of total landings of striped mullet by major county: 1972 – 2002.

6.1.6 Primary Waterbodies of Harvest

The majority of commercial harvest had annually come from state-jurisdiction ocean waters (less than 3 miles) from 1972 to 1993 via the beach seine fishery. On average, 46% of the annual harvest between 1972-1993 was from inshore ocean waters (Figure 6.7). A sharp decline in landings from ocean waters occurred in 1994, and annual landings have remained depressed until present. The proportions of landings from other major water bodies have generally increased, compensating for the landings decline from the ocean (Figure 6.7). Current commercial landings from 1994 to 2002 are now harvested more evenly among; Pamlico Sound (17%), Neuse River (12%), Ocean (less than 3 mi) (12%), Core Sound (11%), Albemarle Sound (11%), Pamlico River (7%), Inland Waterway (6%), Bogue Sound (5%), and New River [4% (Figure 6.7)]. Recently, landings in Croatan Sound have also shown an upward trend, averaging 5% of total harvest from 1999 to 2002.

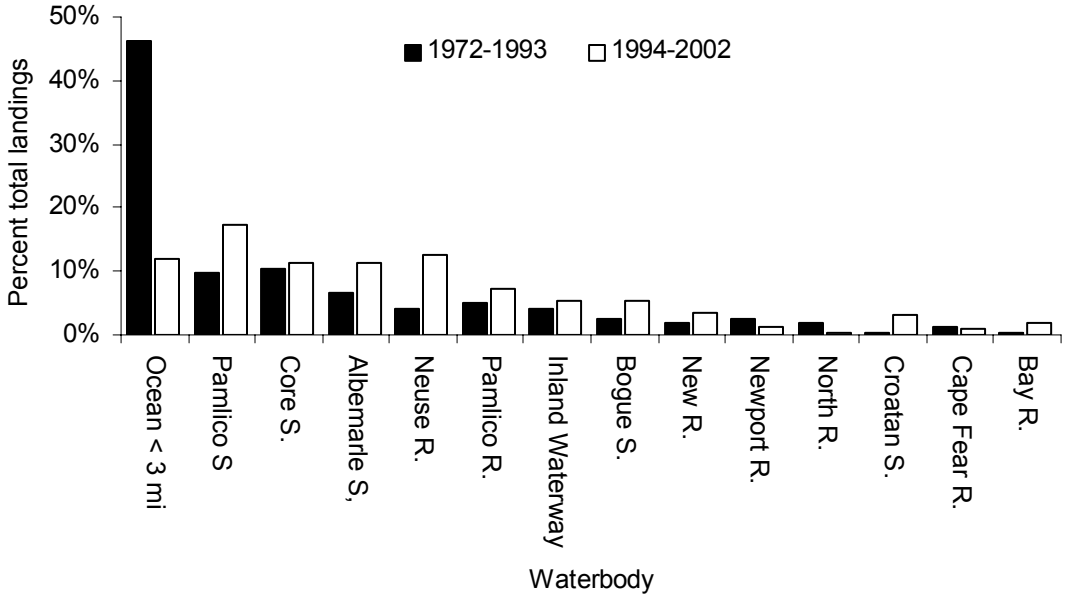

Figure 6.7. Average percentage of total striped mullet landings by waterbody for two distinct time periods: 1972-1993: 1994 - 2002.

6.1.7 Characterization of Striped Mullet Trips

The yearly number of trips with striped mullet harvest has slightly declined, while annual landings have behaved erratically over the short period (1994-2002) since trip tickets have been reported to NCTTP (Figure 6.8). Erratic yearly landings may have resulted from fall hurricane effects. The slight decline in trips may have resulted from the lower price for roe mullet from 1998 to present (Figure 6.4).

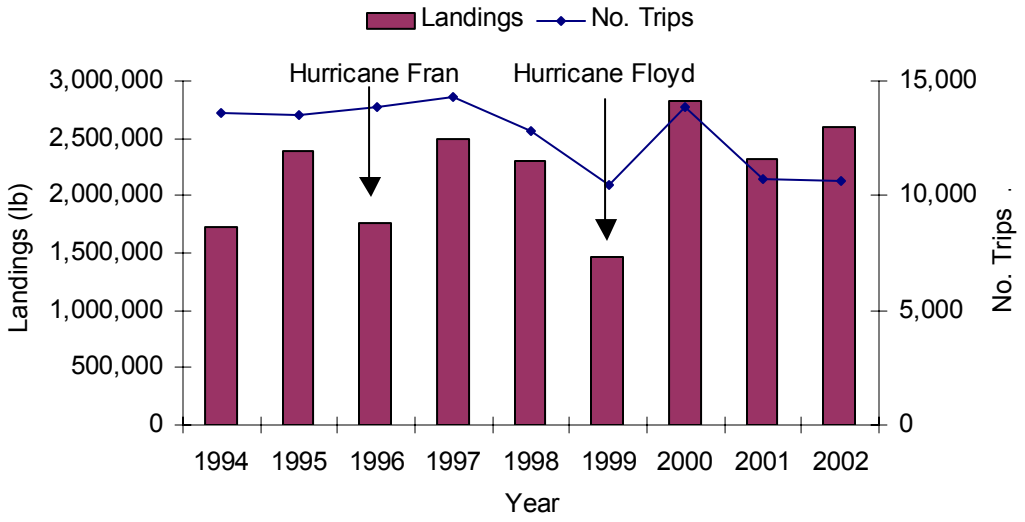

Figure 6.8. Yearly landings (pounds) and number of trips with striped mullet harvest (1994-2002).

Most documented trips in the striped mullet fishery are composed of small catches. Seventy percent of the total number of striped mullet trips between 1994-2002 was composed of catches with less than 100 lb of striped mullet landings (Figure 6.9). Small harvest trips (< 100 lb) are less frequent in the peak months of October and November, implying an increased directed effort for striped mullet during these months. Trips with less than 100 lb of mullet harvest accounted for approximately 10% of the total landings in weight between 1994-2002 (Figure 6.9). Furthermore, catches with less than five lb of striped mullet harvest were the most common trip type, accounting for 21% of total trips (Figure 6.10). Incidental catches of 5 lb striped mullet or less occurs most frequently in the flounder pound net fishery and small mesh set gill net fisheries for spot, white perch, bluefish, spotted seatrout, etc.

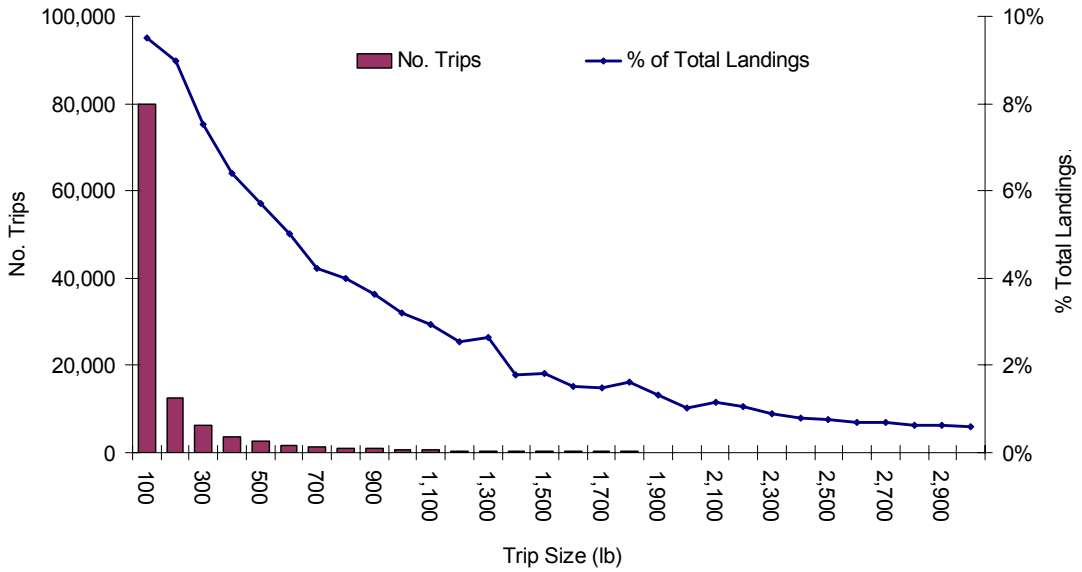

Figure 6.9. Total number of trips in each 100 lb size class of harvest and its percentage of the total landings (1994-2002).

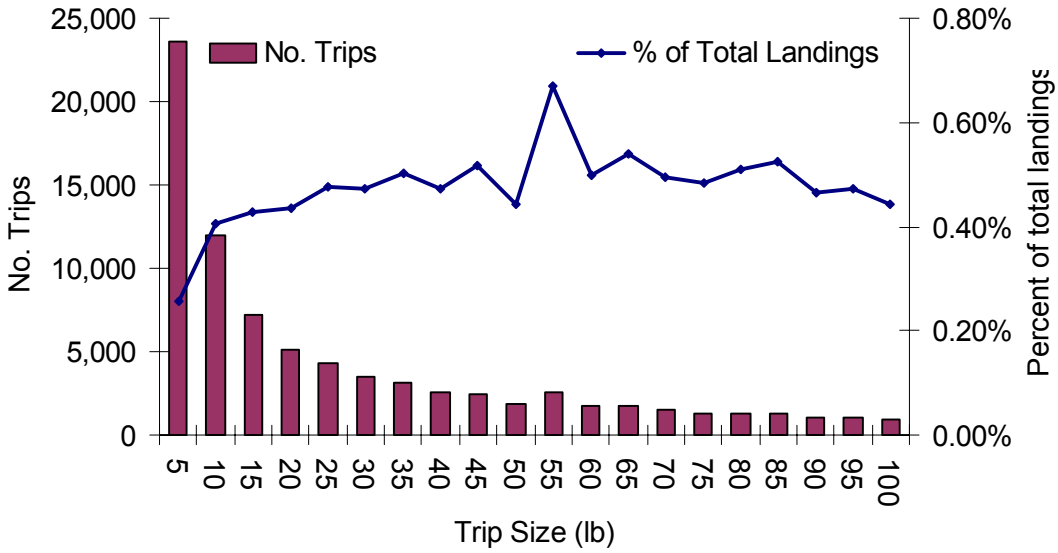

Figure 6.10. Total number of trips and percentage of landings for each 5 lb size class of striped mullet harvested: 1994 - 2002.

6.1.8 Market Grades/ Harvest Composition

Striped mullet harvest is categorized by size and roe grades when purchased by the seafood dealer from the fisherman. Striped mullet landings only began to be recorded by specific market grades on trip tickets in 1994 as extra-small, small, medium, large, jumbo, mixed, red roe, and white roe market categories. Ninety-nine percent of all striped mullet landings were sorted into either mixed (50%), red roe (42%), or white roe (spawning male striped mullet) (7%) market grades from 1994 to 2002 (Table 6.2).

Table 6.2. Average yearly striped mullet landings in each market category: 1994 – 2002.

Market category	Average yearly landings (lb)	Percentage of yearly landings
Mixed	1,081,819	49.79%
Red roe	923,304	42.49%
White	160,633	7.39%
Medium	2,797	0.13%
Jumbo	1,289	0.06%
Large	1,180	0.05%
Small	822	0.04%
X-Small	972	0.04%

Mixed market grade harvest occurs year-round, although more heavily in late summer to early fall and in January, probably associated with increased availability due to schooling during these months (Figure 6.11). Ninety-eight percent of the annual red roe harvest and 94% of the

white roe harvest occurs in October and November (Figure 6.11). Most spawning striped mullet will be graded as mixed after Thanksgiving, even though ripe fish are occasionally harvested into February and March. The roe market shifts from North Carolina to Florida in December.

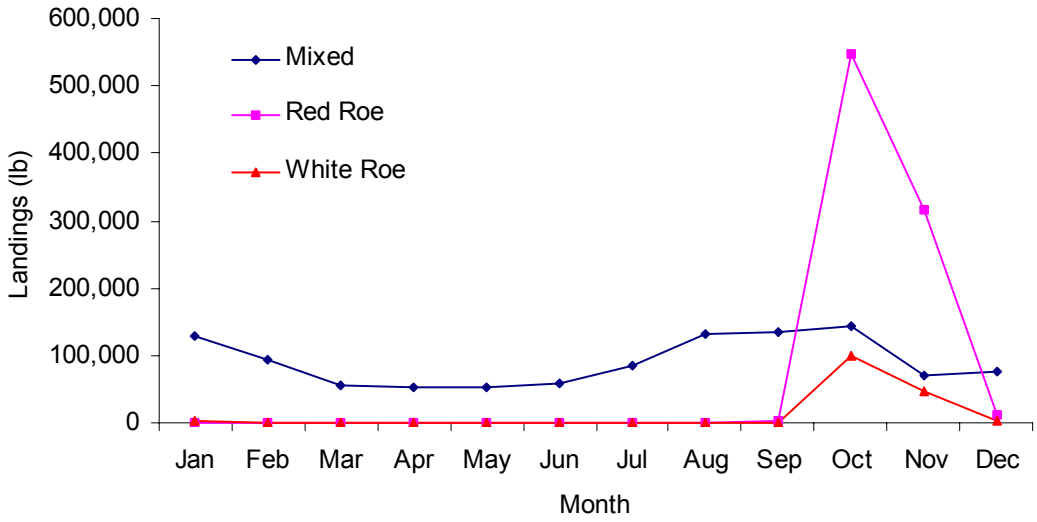

Figure 6.11. Average monthly striped mullet landings in major market categories: 1994 - 2002.

Pronounced year-to-year fluctuations in red roe harvest are evident from 1994 to 2002 (Figure 6.12). Strong weather conditions (i.e. hurricanes, cold fronts) during the fall can profoundly affect annual landings. In addition to limiting fishing opportunities, hurricanes and hard winds can cause spawners to exit inshore areas rapidly and prematurely. Hurricanes Fran and Floyd likely depressed landings in 1996 and 1999.

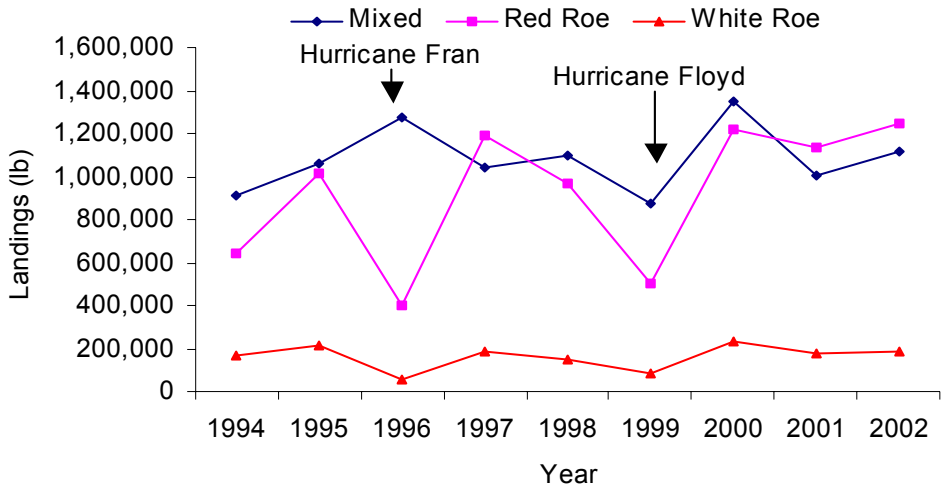

Figure 6.12. Fluctuations in yearly landings in the three major market categories: mixed, red roe, and white roe (1994-2002).

6.1.9 Major gear types used in the fishery

Seines and gill nets have been the two primary gear types involved in the fishery since the earliest documented landings in 1887. From 1887 to 1978, 60% of the total commercial harvest was landed by seines and 39% from gill nets (Figure 6.13). Gill net landings were larger than seine landings in only five of 50 years of available landings data during this time period (Chestnut and Davis 1975; DMF unpublished data). The seine fishery dominated early landings from 1887 to 1934, accounting for 61% of the total harvest (36% from gill nets). Total gill net landings exceeded seine landings (56% to 44%) for a short period, from 1937 to 1940. Seines again accounted for most of the fishery harvest (62% of total landings) from 1950 to 1978 (gill nets were responsible for 37% of total landings).

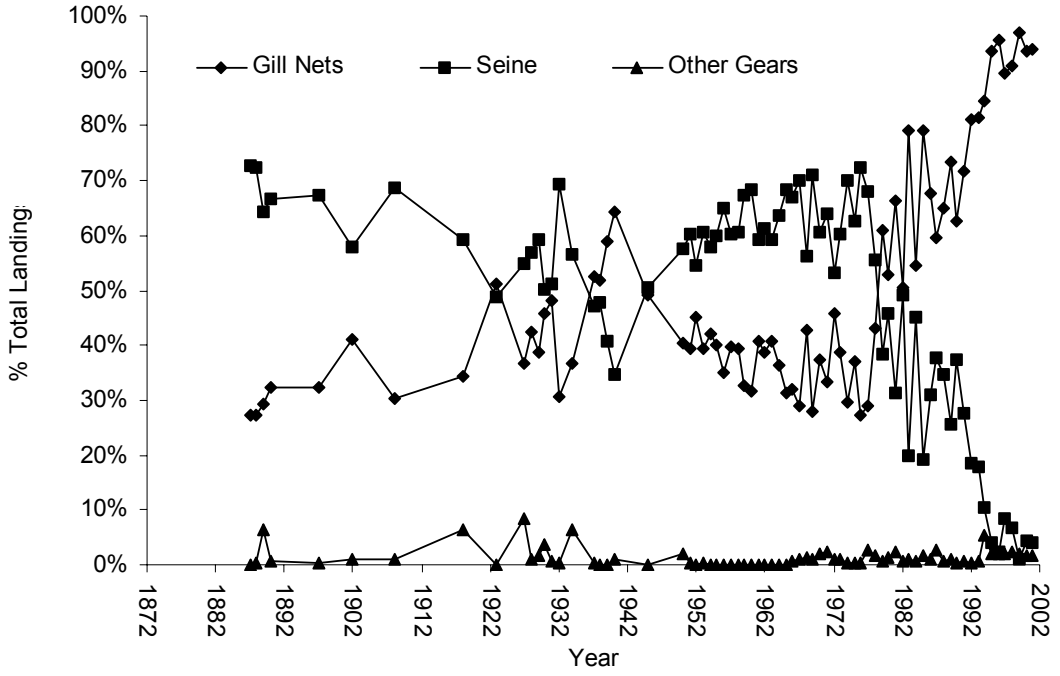

Figure 6.13. Gear trends in the striped mullet fishery; proportion of total yearly landings harvested by gill nets, seines, and other gears (Chestnut and Davis 1975; Bureau of Fisheries; DMF).

Gill nets replaced seines as the dominant gear type in the fishery in 1979 (Figure 6.13). Its yearly proportion of the total fishery landings has steadily increased over the past 24 years. By 2001, 94% of total landings were harvested by gill nets, 4% from seines, and 1% from cast nets.

More detailed landings data with respect to fishing gears became available in 1994 due to the creation of the NCTTP. The number of gears reported in the striped mullet fishery more than doubled between the periods of 1972-1993 and 1994-2002, from 16 to 34 different gear types. A maximum of three gears are recorded by NCTTP for each trip ticket of landings (since 1994). However, NCTTP does not allocate harvest weight to each individual fishing gear reported on the trip ticket when multiple gears are listed. Therefore, unambiguous landings from trip tickets with only one listed gear of harvest were used to proportionally allocate landings

on each multi-gear trip ticket for the following summary.

Current gear types in the fishery (1994 - 2002)

An average of 92% of all landings are annually harvested by gill nets (runaround, set, and drift nets) since 1994. The runaround gill net is responsible for the greatest, single proportion (49%) of total, annual landings in the striped mullet fishery [1994-2002 (Table 6.3; Figure 6.14)]. Set gill nets (combined sinking and floating) annually produced 42% of the harvest from 1994 to 2002. On average, beach seines were responsible for 5.4% of the annual harvest, and cast nets yielded 1.1% from 1994 to 2002.

Table 6.3. Average yearly striped mullet landings by gear: 1994 – 2002.

Gear	Average yearly landings (lb)	Percent total landings
Gill net (runaround)	1,070,382	49.0%
Gill net set (sink)	505,780	23.2%
Gill net set (float)	420,950	19.3%
Gill net (unknown)	5,119	0.7%
Beach seine	17,383	5.4%
Cast net	24,158	1.1%
Pound net	12,210	0.6%
Long haul seine	8,853	0.4%
Others (28)	7,886	0.4%

Gill nets

Runaround gill nets

The importance of runaround gill nets has steadily increased since 1972 (Figure 6.14). Runaround gill netting was a major harvest producer in historic records during the late 1930s (59% of total harvest in 1939), although inconsistency in commercial sampling precludes a more detailed historical fishing gear analysis prior to 1972. The continuing surge in the mid 1990s in runaround gill net landings may have been bolstered by the 1995 gill net closure in Florida State waters. Anecdotal reports from North Carolina fishermen indicate an influx of Florida striped mullet fishermen into North Carolina and subsequent improvements in harvesting methods. More jet drive boats, spotting towers, night fishing, and runaround gill netting were reported by the mid 1990s. Also, expanded fishery rules requiring gill net attendance in additional areas of North Carolina was required for small mesh gill nets (less than 5 inches stretch diameter) beginning in 1998, which may have further prompted a shift from set nets to runaround fishing for mullets. However, the number of trips with runaround gill net landings has not risen since 1997 and landings have increased only slightly (Figure 6.15).

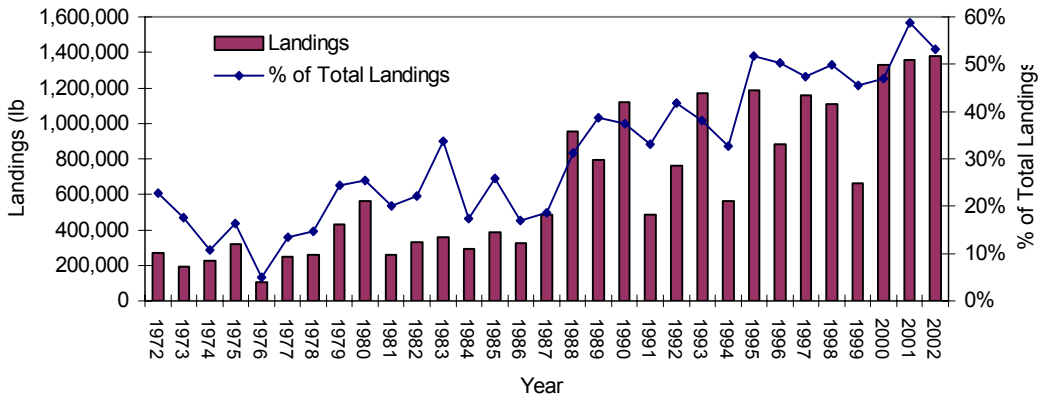

Figure 6.14. Yearly landings and percentage of total yearly landings of striped mullet harvested by runaround gill net: 1972 - 2002.

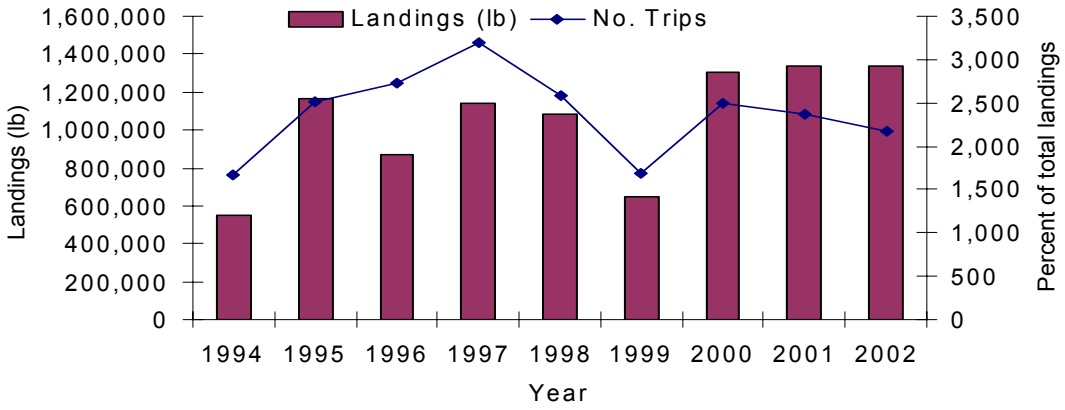

Figure 6.15. Yearly striped mullet landings and number of trips in the runaround gill net fishery: 1994 - 2002.

Most runaround gill net trips and landings occur in October and November during the roe season (Figure 6.16). Mesh sizes range from 2 ¾ in. to 5 in. stretch, although most runaround nets are between 3 1/8 and 4 in. stretch mesh (DMF data).

Ninety-four percent of runaround gill net landings are distributed among 14 waterbodies, with the largest contributions from Pamlico Sound (21%), Neuse River (16%), Core Sound (11%), and the Inland Waterway [9% (Table 6.4)]. Runaround gill netting has increased considerably in Croatan Sound since 1994, increasing from 0.005% of the total runaround harvest in 1994 to 13% in 2002. Runaround landings from other waterbodies have fluctuated without much trend from 1994 to 2002 (Figure 6.17).

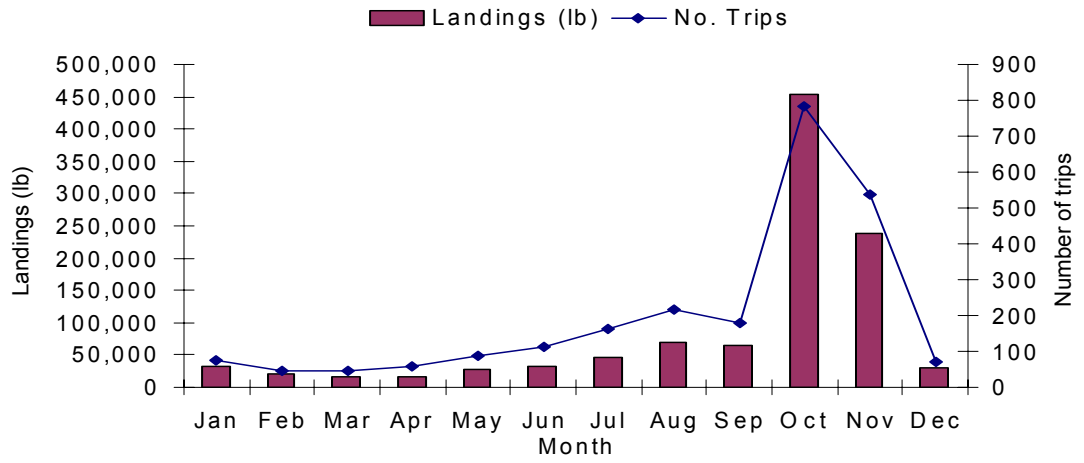

Figure 6.16. Average monthly striped mullet landings and number of trips in the runaround gill net fishery: 1994 - 2002.

Table 6.4. Average yearly striped mullet landings (lb) and percentage of total runaround gill net landings by waterbody: 1994 - 2002.

Waterbody	Average yearly landings (lbs)	Percent total runaround gill net landings
Pamlico Sound	222,403	21%
Neuse River	169,686	16%
Core Sound	120,250	11%
Inland Waterway	99,105	9%
Ocean < 3miles	74,451	7%
Bogue Sound	63,079	6%
Croatan Sound	55,361	5%
New River	54,346	5%
Pamlico River	50,545	5%
Albemarle Sound	30,789	3%
Bay River	22,248	2%
Roanoke Sound	16,416	2%
Newport River	16,399	2%
Other 16 watebodies	61,865	6%

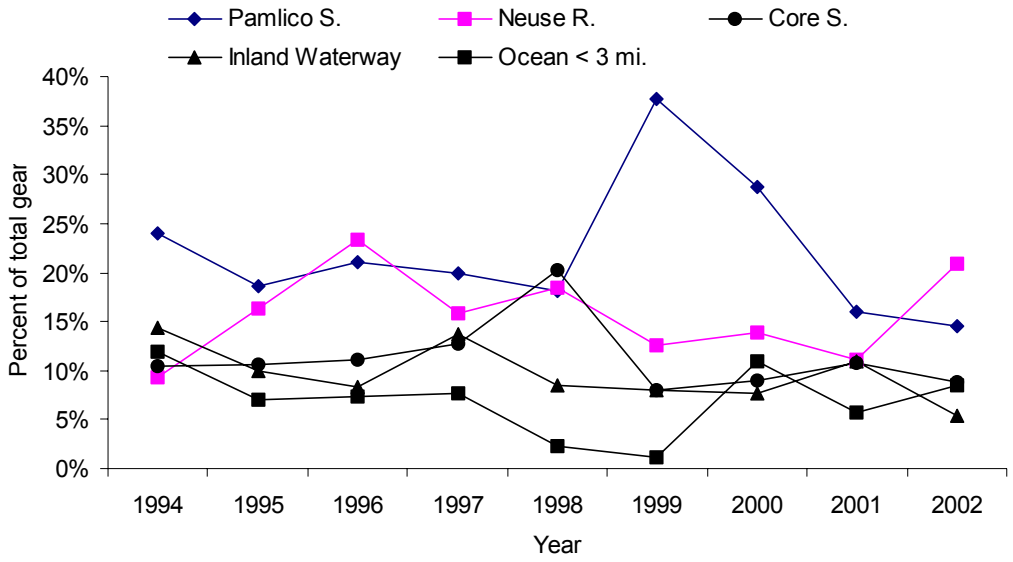

Figure 6.17. Yearly percentage of total runaround gill net striped mullet landings by major waterbody: 1994 - 2002.

Set gill nets

Set gill nets have also risen in importance since 1972, although its proportion of the total landings has not increased since the mid 1980s (Figure 6.18). Two types of set nets are recorded by NCTTP, floating and sinking gill nets. Sinking set gill nets are defined as stationary gill nets with the top line below the surface of the water (NCTTP 2002). Striped mullet landings from floating set nets have declined, while sinking set nets have fluctuated without trend since 1994 (Figure 6.19). Most set gill nets for mullet are set from top to bottom in the water column, so fishermen and dealers may sometimes arbitrarily report landings as either gill net (float) or gill net (sink) on trip tickets without recognition of the set net definitions provided by NCTTP. Trip ticket inaccuracy by dealers with respect to floating and sinking set nets is a potential caveat to consider, although its magnitude is unknown. Floating and sinking set gill net landings are combined in the ensuing description of the set gill net fishery.

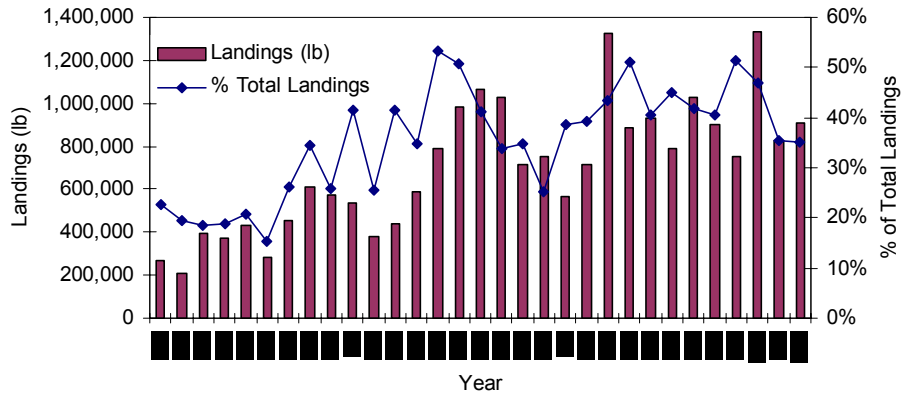

Figure 6.18. Yearly landings and percentage of total yearly striped mullet landings harvested by set gill nets from 1972 to 2002.

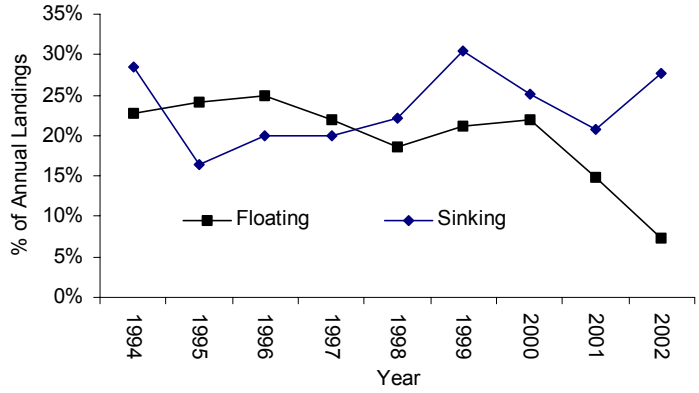

Figure 6.19. Percentage of annual striped mullet landings harvested by floating and sinking set gill nets from 1994 to 2002.

The number of trips with striped mullet landings harvested by set gill nets has declined slightly from 1994 to 2002 (Figure 6.20). Yearly landings between 1994-2002 have fluctuated only moderately with no increasing or decreasing trend (Figure 6.20).

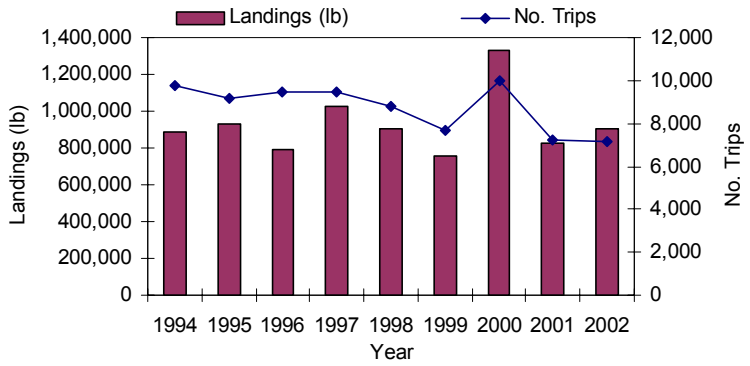

Figure 6.20. Yearly striped mullet landings (lb) and number of trips by set gill nets (1994-2002).

The number of set gill net trips with striped mullet harvest is greatest in October and November (Figure 6.21). The number of set gill net trips with striped mullet harvest is still elevated in winter and spring months (January to April) compared to runaround gill net trips. However, landings from set nets during the winter and spring are small, reflecting more incidental striped mullet capture in other non-mullet targeted gill net fisheries. A wide range of set gill net mesh sizes (3 in. – 7 in. diameter stretched mesh) is found with striped mullet landings, also reflecting a wide array of different target fisheries (i.e. spot, flounder, white perch, bluefish, spotted seatrout, menhaden).

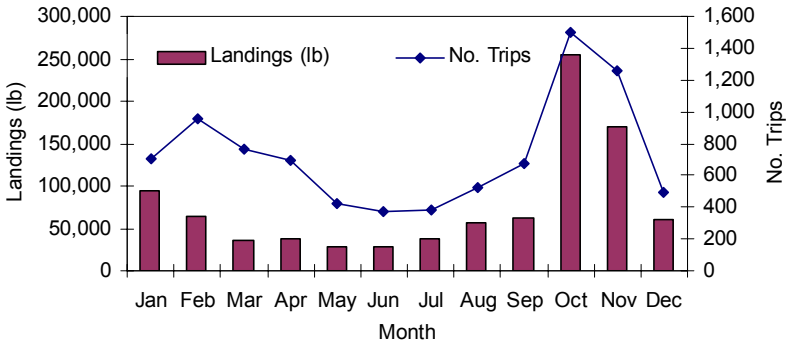

Figure 6.21. Average monthly landings (lb) and number of trips by set gill nets (1994-2002).

Eight-two percent of set gill nets striped mullet landings are harvested in Albemarle Sound (22.3%), Pamlico Sound (15.4%), Core Sound (11.4%), Pamlico River (11.1%), Neuse River (11.0%), Atlantic Ocean [< 3 mi. (5.4%)], and Bogue Sound (5.3%). Other waterbody landings by set gill nets are shown in Table 6.5. Fluctuations in the share of landings taken in waterbodies by set gill nets are indicated in Figure 6.22.

Table 6.5. Average yearly striped mullet landings (lb) and percentage of total set gill net landings by waterbody.

Waterbody	Average yearly landings (lbs)	Percent total sink gill net landings
Albemarle Sound	207,633	22%
Pamlico Sound	143,881	15%
Core Sound	105,888	11%
Pamlico River	103,812	11%
Neuse River	102,829	11%
Ocean < 3miles	50,709	5%
Bogue Sound	48,962	5%
New River	22,123	2%
Inland Waterway	19,330	2%
Bay River	17,673	2%
Pungo River	14,558	2%
Croatan Sound	12,712	1%
Currituck Sound	11,137	1%
Newport River	10,119	1%
Pasquotank River	8,990	1%
Other 19 watebodies*	51,107	6%

*each water <1% of total

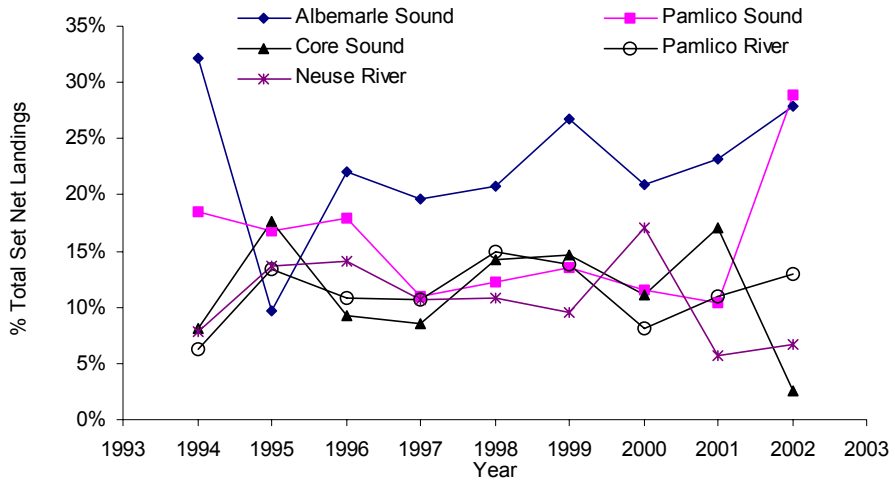

Figure 6.22. Yearly set gill net striped mullet landings by major waterbody.

Beach seines

The historic striped mullet seine fishery was predominantly composed of beach crews scattered among established territories along the central coastline of North Carolina, from Ocracoke south along Core, Shackleford, and Bogue banks (Simpson and Simpson 1994). Spotters along the beach would alert boat crews of southwestward, ocean migrating mullet schools. A long seine was deployed by small boat or skiff to intercept the oncoming school. Mullet were hauled in by manpower, horses, oxen, or tractor in later years (Simpson and Simpson 1994). Stop nets (stationary nets not intended to gill fish, used to impede the

movement of schooling fish so that they can be harvested with a seine) were employed along Bogue Banks.

The harvest proportion of annual landings from the beach seine fishery has dwindled since 1972 (Figure 6.23) and landings have fluctuated greatly since 1994 (Figure 6.24). Landings by beach seines occur almost entirely in October and November (Figure 6.25). Extremely poor landings in 1996 and 1999 were probably the result of fall hurricanes and strong weather conditions, which have a particularly profound effect on stop net harvest because of its limited fishing season. Beach seine landings are harvested in Carteret (90%), Dare (6%), Hyde (2%), and Onslow Counties (2%).

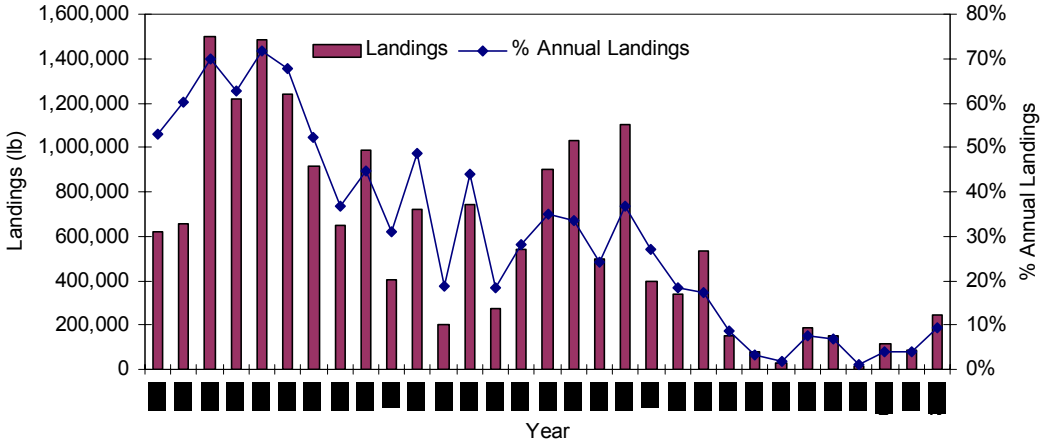

Figure 6.23. Yearly striped landings (lb) and percentage of total yearly landings harvested by beach seines from 1972 - 2002.

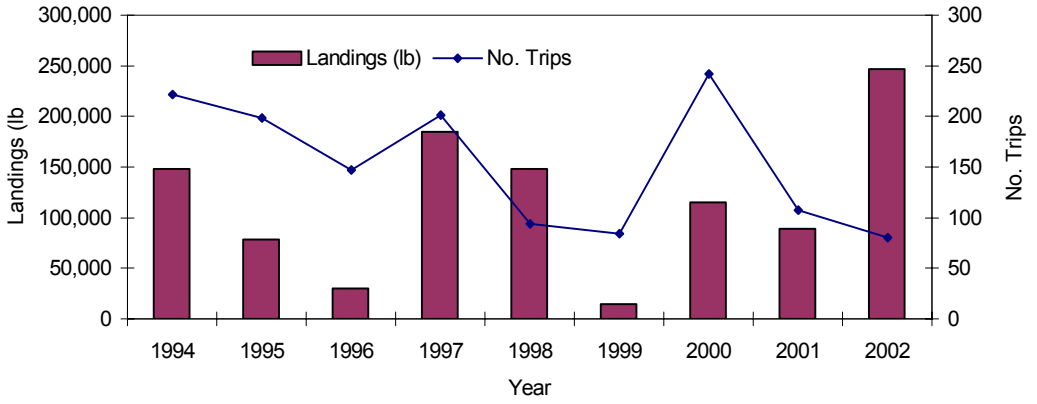

Figure 6.24. Yearly striped mullet landings (lb) and number of trips by beach seines: 1994 - 2002.

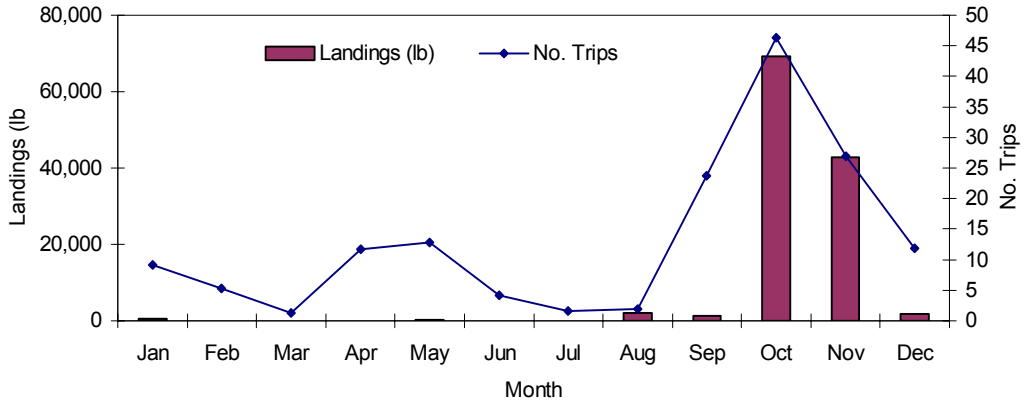

Figure 6.25. Average monthly striped mullet landings(lb) and number of trips by beach seines: 1994-2002.

The stop net fishery accounts for approximately 74% of the landings in the current striped mullet seine fishery (2000-2002). The stop net fishery has operated under fixed seasons, and net and area restrictions since 1993. Stop nets are limited in number (four), length (400 yards), and mesh sizes (minimum eight inches – outside panels, six inches - middle section). Stop nets are only permitted along Bogue Banks (Carteret County) in the Atlantic Ocean between October 1 through November 30.

Landings from the other, smaller, seine fishery are harvested in ocean waters (< 3 mi.), primarily in Carteret, Dare, and Hyde counties. Typically, monofilament gill nets (200-300 yards) are used to intercept ocean schooling striped mullets and hauled onto the beach as functional seines. Ninety-two percent of the striped mullet landings in this fishery occur in October and November during the fall spawning migration. Outside of October and November, much of this seine fishery targets other species. From December through September seining with gill nets for spot, spotted seatrout, sea mullet, etc. along the Outer Banks accounts for many of the trips shown in Figure 6.25.

Cast Nets

Cast net harvest is predominantly sold as bait. NCTTP records of striped mullet landings from cast nets began in 1994. Cast net landings only represent 1% of the total mullet landings from 1994 to 2002 yet show a slight upward trend (Figure 6.26). Striped mullet landings from cast nets in 2002 were 1.5% of the total yearly landings.

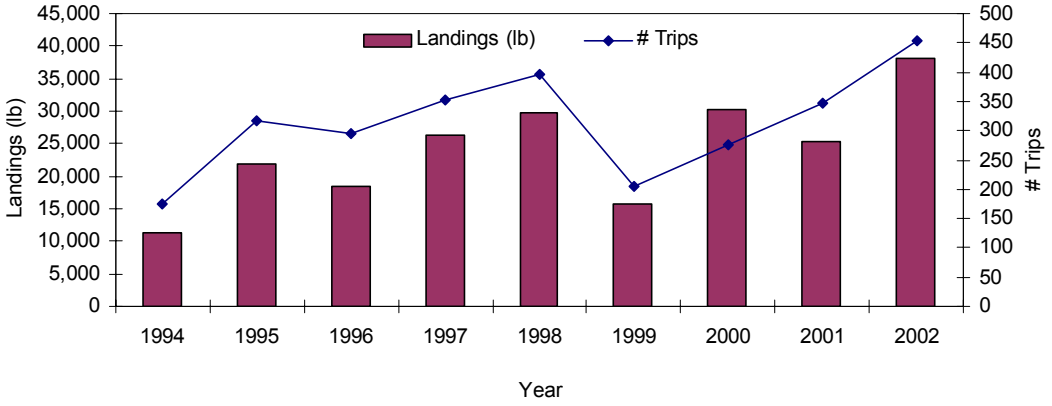

Figure 6.26. Yearly striped mullet landings (lb) and number of trips with landings from cast nets: 1994-2002. Note: a single harvest is sometimes sold to multiple dealers, which increases the total number of cast net trips relative to other gear types.

Cast netted striped mullet landings and the number of trips with cast netted striped mullet harvest are sharply seasonal. Eighty-three percent of the annual cast net harvest occurs in September and October (Figure 6.27). Cast net landings coincide with the large, September, ocean, migration of white mullet. Monthly cast net landings decline to 9% of the yearly total in November. Recent DMF research indicated that >95% of September and October cast netted bait harvest was white mullet. Conversely, nearly all bait mullet landed in November were identified as striped mullet.

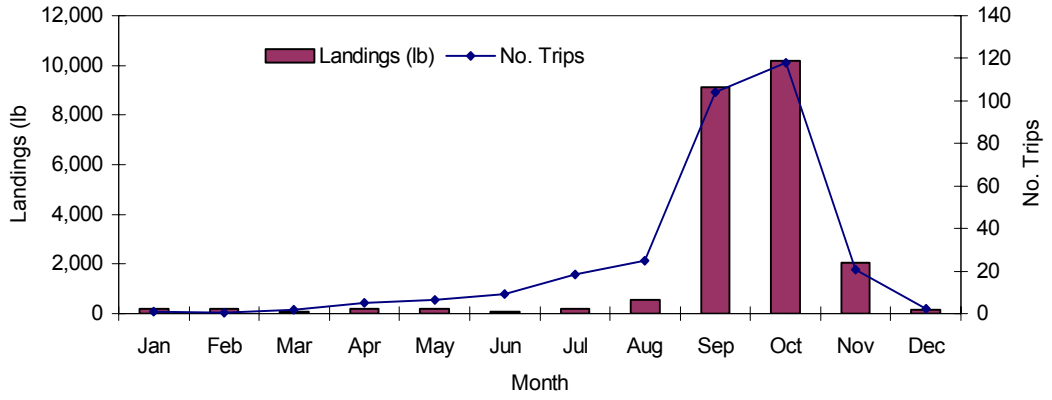

Figure 6.27. Average monthly striped mullet landings (lb) and number of trips from cast nets: 1994 - 2002.

The fall cast net fishery primarily targets mullets that will be used as bait, either as cut, whole (frozen), or live bait, much unlike other mullet fisheries that almost exclusively target roe fish during this period. Only 2% of the total cast net landings were graded as red roe between 1994 and 2002. Ninety-three percent were graded as mixed, 2% small, 2% x-small, and 1% white roe.

Ninety-two percent of cast net mullet landings are harvested in Dare County (85%) and Carteret County (7%). Most of the total landings are captured in state jurisdiction ocean waters

[< 3 mi. (64%)], Pamlico Sound (21%), and White Oak River (5%). The remaining 10% of the landings are harvested among 19 other waterbodies.

6.2 RECREATIONAL

Few anglers target striped mullet by hook and line. However, striped mullet and white mullet are a popular bait fish for anglers targeting a variety of inshore and offshore fish. Mullets are used as live, strip, cut and trolling baits (Nickerson, Jr. 1984). Young-of-the-year (YOY) mullets, commonly known as finger mullet, are often caught by anglers using cast nets. Mullets caught in cast nets by anglers generally occurs during the summer and fall with the majority caught in September and October. The fall harvest of bait mullet coincides with the southward migration of YOY striped and white mullet.

Marine Recreational Fisheries Statistics Survey

Accurate recreational harvest estimates of striped mullet are difficult to obtain. The Marine Recreational Fisheries Statistics Survey (MRFSS) is used to estimate the recreational harvest of marine finfish in North Carolina. The survey is designed to sample anglers who use rod and reel as the mode of capture. However, the majority of the striped mullet sampled by MRFSS creel clerks are caught with cast nets. It can be difficult for fishermen to accurately estimate the number of striped mullet harvested as bait by cast nets. Non-reporting of bait is also a potential problem in the survey. The lack of discrimination between striped mullet and white mullet is another major limitation of the MRFSS survey. It is likely that white mullet are misidentified and added in the harvest estimates for striped mullet. MRFSS does not compute white mullet harvest estimates and does not include that species in its North Carolina survey. Mullets released by anglers are not observed by MRFSS creel clerks and therefore cannot be identified to the species level

Harvest estimates include the proportional standard error (PSE), which is a measure of precision of the estimate. The PSE expresses the standard error (SE) as a percentage of the harvest estimate ((SE/harvest estimate) * 100). Precision is inverse to the PSE with small PSEs indicating a more precise estimate and larger PSE indicating imprecise estimates. Commonly, estimates with a PSE of 20 or less are considered useable, while estimates with PSE greater than 20 are considered unreliable. Improvements in striped mullet data collection by MRFSS occurred in 2001, so prior data were not used in this summary (Table 6.6). The PSE associated with bimonthly estimates were fairly high and were not very precise, but the annual PSE for 2001 and 2002 were acceptable.

Table 6.6. Number of mullets (striped and white) harvested and released alive by anglers by wave, for 2001-2002. (Courtesy of North Carolina MRFSS)

	2001		2002	
	Number harvested	PSE	Number harvested	PSE
Wave 2 (Mar.-Apr.)	68	100.1		
Wave 3 (May-Jun.)	108,418	29.4	101,598	32.0
Wave 4 (Jul.-Aug.)	205,489	27.4	360,592	18.7
Wave 5 (Sep.-Oct.)	556,710	29.6	1,076,024	20.2
Wave 6 (Nov.-Dec.)	8,859	100.0	48,838	67.0
Total	879,544	20.2	1,587,052	14.7

	2001		2002	
	Number released	PSE	Number released	PSE
Wave 2 (Mar.-Apr.)	0	0.0		
Wave 3 (May-Jun.)	69,488	45.5	28,646	39.6
Wave 4 (Jul.-Aug.)	130,502	46.0	193,816	25.0
Wave 5 (Sep.-Oct.)	157,955	29.8	292,521	28.8
Wave 6 (Nov.-Dec.)	0	0.0		
Total	357,945	23.1	514,983	19.0

Recreational Commercial Gear License Survey

Another source of recreational landings of striped mullet comes from people who possess a Recreational Commercial Gear License (RCGL) that allows them to use a limited amount of commercial gear for personal use. The DMF began surveying holders of the RCGL in March of 2002 with the purpose of obtaining catch and effort estimates for the RCGL user group. The survey questionnaires were distributed monthly to 30% of the RCGL population from each county requesting data such as waterbodies commonly fished, types and amounts of gear used, number and weight of individual species kept, and number of individual species discarded at sea. Thirty-four percent of all individuals who were mailed a questionnaire returned the questionnaire to the DMF. Therefore, the survey program, on average, successfully surveyed 10.2% of the total RCGL population each month during 2002. Demographic information obtained at the time the licenses were sold was used to examine if the returned surveys were representative of the RCGL population to ensure the samples taken could be used to generalize about the total RCGL population. Additionally, the survey responses for total catch and number of trips were examined for possible outliers using standard statistical methods. Monthly effort and catch reported by the survey respondents were extrapolated to the total RCGL population.

Extrapolation of the sample to the total RCGL population requires three components: 1) the percent of individuals actively using each type RCGL gear from the sample, 2) the mean catch for each individual species by each gear type, and 3) the total number of RCGL holders. The summation of the multiplication of these items for each gear type yields the estimated total catch and effort for an individual species for the entire RCGL population. To provide a measure of reliability (precision), PSE was calculated for effort and catch estimates for each species. Small mesh gill nets (less than 5” stretched mesh) were the only RCGL authorized gear that encountered striped mullet. The median yardage of small mesh gill net used was 100 yards. Bogue Sound, Pamlico River and Neuse River were the major waterbodies reported with fishing

activity for striped mullet. These areas constituted 34% of all small mesh gill net trips containing striped mullet (Table 6.7). The total estimated harvest for striped mullet during 2002 by RCGL holders was 66,305 striped mullet with a total weight of 64,213 pounds (Table 6.8). July, August, and October had the highest reported landings of striped mullet with the peak occurring in October (15,762 lb.). The percent of striped mullet discarded ranged from 3% to 13% of the total number caught and averaged 9% for the year (Table 6.8). June (13%) and August (11%) were the months with the highest discard rates. Annual PSEs were acceptable for trips and landings but not for discards.

Table 6.7. Estimated number of participants and trips containing striped mullet by waterbody during 2002.

Waterbody	Number of participants	Number of trips	Percent of trips
Bogue Sound	362	1,245	12.4
Pamlico River	202	1,119	11.1
Neuse River	317	1,077	10.7
Albemarle Sound	252	851	8.5
Shallotte River	202	664	6.6
Pamlico Sound	177	576	5.7
IWW (Onlsow)	126	569	5.7
Atlantic Ocean (S of Hatteras)	131	458	4.6
Topsail Sound	104	442	4.4
Roanoke River	44	398	4.0
Bay River	160	380	3.8
Core Sound	76	346	3.4
Masonboro Sound	77	291	2.9
IWW (Bruswick/Newhanover)	92	258	2.6
New River	67	225	2.2
IWW (Pender County)	45	197	2.0
Cape Fear River	74	187	1.9
White Oak River	63	179	1.8
Pungo River	40	96	1.0
Currituck Sound	15	93	0.9
Lockwood Folly	37	92	0.9
Newport River	36	71	0.7
Stump Sound	31	68	0.7
Croatan Sound	18	61	0.6
Atlantic Ocean (N of Hatteras)	9	53	0.5
Chowan River	15	46	0.5
Total	2,772	10,043	

Table 6.8. Estimated catch statistics for striped mullet in RCGL holder small mesh gill nets during 2002.

	Number of	Trips		Landed				Discarded		Total	
Month	participants	number	PSE	pounds	PSE	number	PSE	number	PSE	number	PSE
Jan.	26	231	56	180	71	218	76			218	76
Mar.	166	1,311	41	2,266	51	2,305	40	442	52	2,747	37
May	263	665	15	7,972	56	6,421	46	201	79	6,622	44
Jun.	468	1,359	10	6,493	20	7,020	20	1,087	55	8,106	18
Jul.	194	865	24	10,037	67	10,695	65	787	75	11,482	61
Aug.	346	1,403	18	9,130	30	10,294	29	1,243	72	11,537	30
Sep.	450	1,281	9	6,303	28	6,532	21	552	40	7,084	20
Oct.	533	1,988	10	15,762	41	16,298	41	1,608	47	17,906	38
Nov.	283	840	10	3,758	22	4,182	19	495	47	4,677	17
Dec.	42	101	25	2,311	89	2,340	92	135	93	2,475	86
Total		10,043	6	64,213	18	66,305	17	6,549	24	72,854	16

7. DESCRIPTION OF THE SOCIOECONOMIC CHARACTERISTICS OF THE FISHERY

7.1 DEFINITIONS

Commercial fishing – Fishing in which fish harvested, either in whole or in part, are intended to enter commerce or enter commerce through sale, barter or trade. Since 1999, a commercial fisherman in North Carolina is required to have a license issued by the North Carolina Division of Marine Fisheries (DMF) and is allowed only to sell to a licensed dealer.

Ex-vessel price and value - The total landed dollar amount of a given species (or species landing condition and market category). Example: 100 lbs. of striped mullet at a PRICE of $0.80 per pound will have a VALUE of $80. These values represent the amounts paid to a fisherman by a seafood dealer.

Fishing Trip – A period of time over which fishing occurs. The time spent fishing includes configuring, deploying, and retrieving gear, clearing animals from the gear, and storing, releasing or discarding catch. When watercrafts are used, a fishing trip also includes the time spent traveling to and from fishing areas or locales and ends when the vessel offloads product at sea or returns to the shore. When fishing from shore or man-made structures, a fishing trip may include travel between different fishing sites within a 24-hour period.

Inflation-adjusted values – Inflation is a general upward price movement of goods and services in an economy, usually as measured by the Consumer Price Index (CPI). Ex-vessel prices and values can be adjusted (deflated) according to the CPI to remove the effects of inflation so that the value of a dollar remains the same across years. Inflation adjusted values allow for easier understanding and analysis of changes in values.

Recreational Fishing – A recreational fishing trip is any trip for the purpose of recreation from which none of the catch is sold or bartered. This includes trips with effort but no catch. Anglers who wish to use limited amounts of commercial fishing gear in joint and coastal waters under DMF jurisdiction are required to have a Recreational Commercial Gear License (RCGL).

7.2 COMMERCIAL FISHING

7.2.1 Ex-vessel value and price

DMF began collecting commercial value statistics in 1972. The trip ticket program began in 1994 and it was mandated that all commercial landings be reported to DMF. Reporting the value of the landing continues to remain optional. It is also useful to tie the value of annual landings back to an established baseline to control for the effects of inflation. Changes in landings values from year to year since 1972 can be more clearly understood after removing the influence of changing dollar values.

From 1974 to 1987, total statewide landings value remained relatively stable as shown in Figure 7.1. There was a large demand increase in 1988 due to an opening of Asian markets for striped mullet roe. This demand led to increases in pounds landed and significantly higher ex-vessel prices per pound (see Figure 7.2). Beginning in 1998

ex-vessel prices began to drop due to a slowing of the Asian economy and fewer processors buying striped mullet and roe from North Carolina fishermen.

Inflation-adjusted figures (deflated to the value of a dollar in 1972) typically show less volatility. Nonetheless, the 1990 high of $595,430 (inflation-adjusted) is nearly seven times greater than the lows of approximately $87,000 of 1973 and 1983. The total value of striped mullet has varied greatly from year to year since 1990. When accounting for inflation, the value of annual landings has been in a slight overall downward trend. However, the primary reason for the volatility from year to year has been a direct result of the sharp changes in pounds landed from year to year.

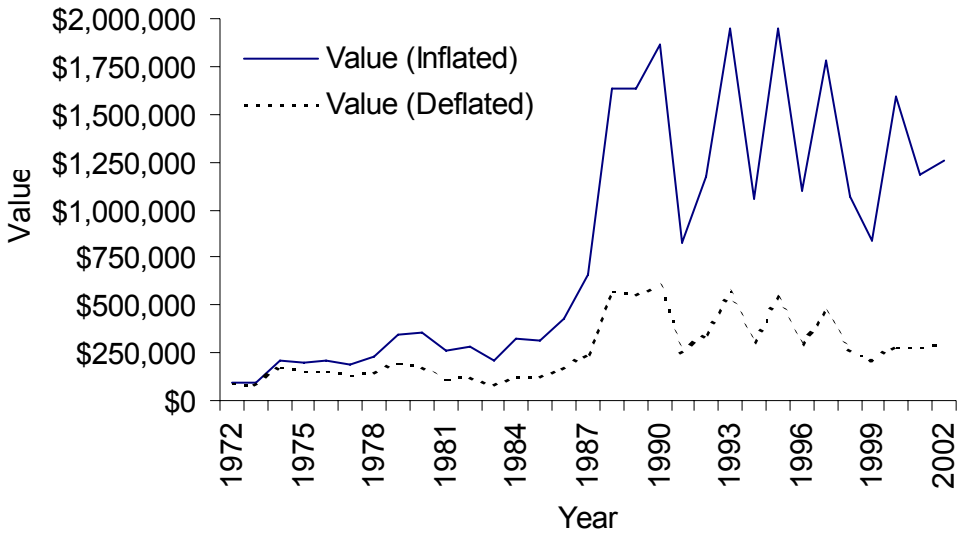

Figure 7.1. Value of striped mullet landings in North Carolina: 1972 – 2002 (DMF Trip Ticket Program).

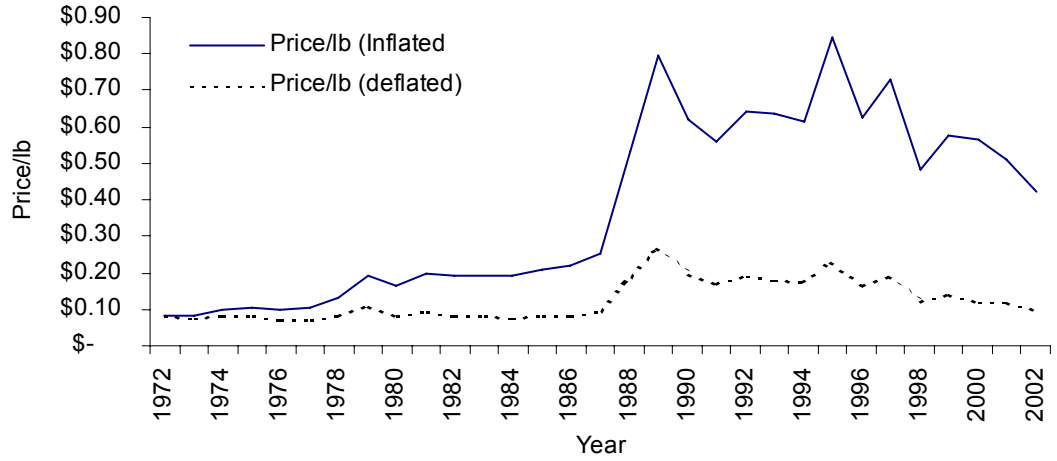

Figure 7.2. Average price per pound of striped mullet landings in North Carolin: 1972 – 2002 (DMF Trip Ticket Program).

The average price per pound paid to the fisherman did not vary much between 1972 and 1987 (Figures 7.2). The price per pound more than doubled in 1988 with the opening of the Asian roe market. Since 1990, the average price per pound has remained higher than prices prior to 1988. Nevertheless, the overall trend has been towards a lower price per pound. The inflation-adjusted price per pound reached a high of $0.27 in 1990. By 2001, it had dropped to about $0.12 per pound, only $0.04 per pound higher than in 1972.

The price per pound tends to fluctuate in a single year depending on the month the fish are harvested. October and November traditionally have brought higher prices per pound primarily because of the increased availability of fish with red roe in those months. However, in recent years, demand for red roe in the fall has not been as strong. As shown in figure 7.3, the price has remained relatively constant all year long in recent years with only a smaller jump in price per pound during the red roe season. The reduction in value may be due to several factors: lowered demand in the Asian market, fewer companies purchasing mullet roe, and an excess of roe fish during those months.

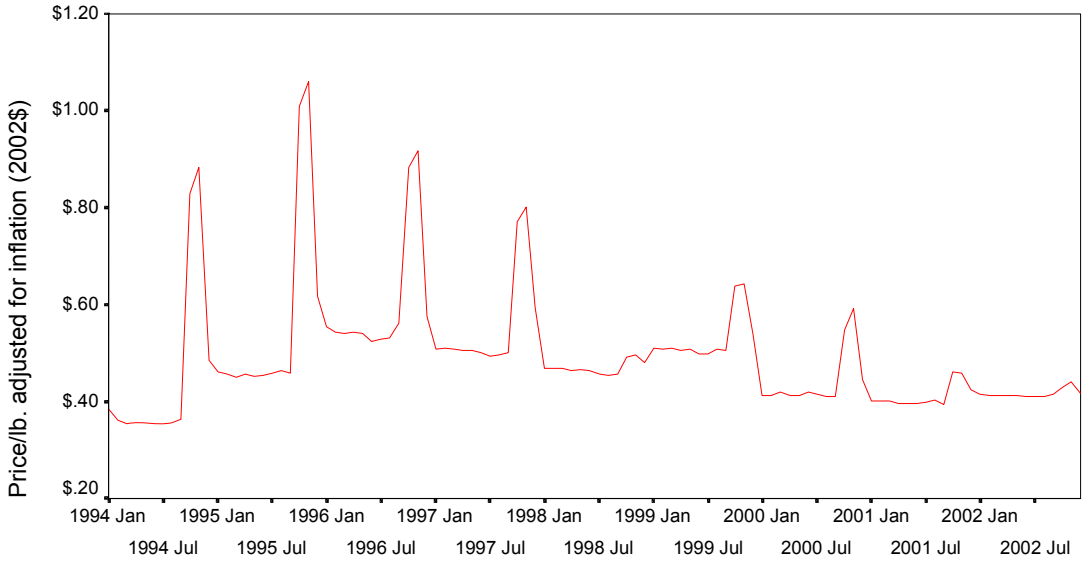

Figure 7.3. Average price per pound of striped mullet by month from 1994 – 2002 and adjusted for inflation (DMF Trip Ticket Program).

7.2.2 Gear and Price

From 1994 – 2002, 92% of all striped mullet were caught using gill nets. An additional 5% were caught using beach seines and 1% in cast nets. The remaining 2% were caught using other gears such as pound nets, pots, or trawls (Figure 7.4).

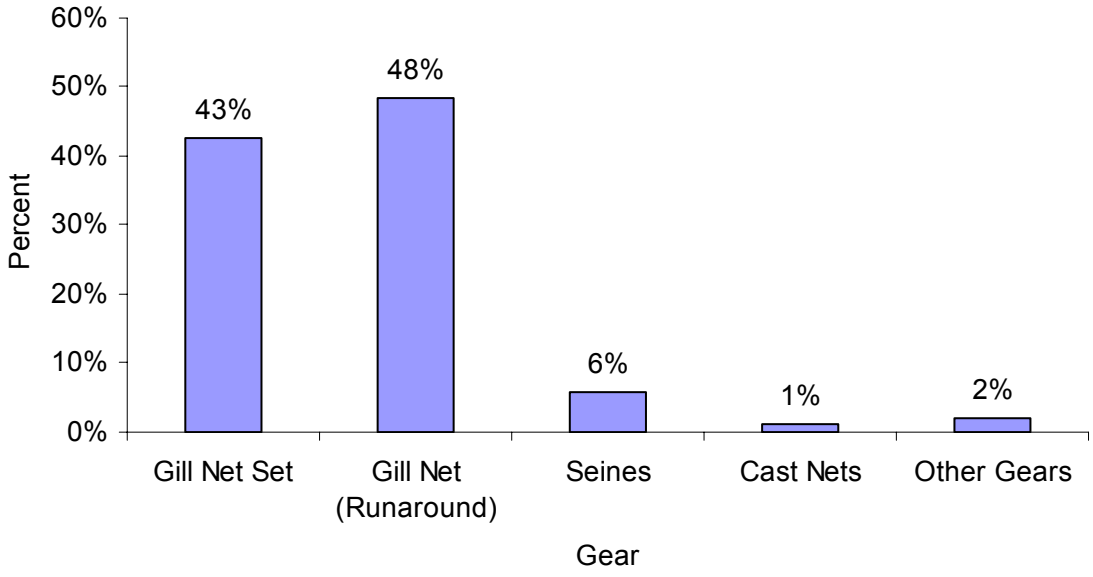

Figure 7.4. Percent of landings by gear used to harvest striped mullet in all North Carolina waters: 1994 – 2002 (DMF Trip Ticket Program).

Table 7.1 shows the number of pounds landed, the total value, and the price per pound for each of the gears listed in Figure 7.3 by year from 1994 – 2002. Gill nets were the primary gear used in each of these years with runaround gill nets accounting for more pounds landed in six of the nine years.

Beach and haul seine landings along with runaround gill nets typically bring a higher price per pound than landings from different gears, particularly between 1994 and 1997. By 1998, seine and runaround gill net landings only received a slightly higher price per pound than other gears.

Landings from all gill nets and seines were hampered by summer and fall hurricanes in 1996 and 1999. In both of these years, landings were significantly lower than the preceding and succeeding years. Beach seine landings in these years were approximately one third to one tenth of what they normally had been.

When the gill net ban was enacted in Florida in 1995, some fishermen came to North Carolina waters to fish for striped mullet. Florida fishermen brought techniques such as using spotting towers that were different from what the North Carolina fishermen had used, but readily adopted.

Table 7.1. The average price per pound for striped mullet using different gears for the years 1994 – 2002 (DMF Trip Ticket Program).

Year	Gear	Pounds	Value	Inflation Adjusted Value	Price	Inflation Adjusted Price	Year	Gear	Pounds	Value	Inflation Adjusted Value	Price	Inflation Adjusted Price
1994	Gill Net Set	882,648	$428,322	$120,830	$0.49	$0.14	1999	Gill Net Set	754,620	$413,408	$103,724	$0.55	$0.15
	Gill Net (Runaround)	555,731	$408,395	$115,208	$0.73	$0.21		Gill Net (Runaround)	656,638	$397,649	$99,770	$0.61	$0.17
	Seines	178,869	$150,069	$42,335	$0.84	$0.24		Seines	15,439	$9,966	$2,500	$0.65	$0.18
	Cast Nets	10,206	$4,040	$1,140	$0.40	$0.11		Cast Nets	15,698	$7,775	$1,951	$0.50	$0.14
	Other Gears	98,786	$67,864	$19,145	$0.69	$0.19		Other Gears	18,324	$10,065	$2,525	$0.55	$0.15
	Total	1,726,240	$1,058,690	$298,657	$0.61	$0.17		Total	1,460,718	$838,863	$210,471	$0.57	$0.16
1995	Gill Net Set	949,648	$744,118	$204,111	$0.78	$0.22	2000	Gill Net Set	1,333,219	$668,470	$162,238	$0.50	$0.14
	Gill Net (Runaround)	1,162,126	$1,045,410	$286,756	$0.90	$0.25		Gill Net (Runaround)	1,316,307	$819,999	$199,014	$0.62	$0.18
	Seines	95,609	$78,482	$21,527	$0.82	$0.23		Seines	125,278	$79,626	$19,325	$0.64	$0.18
	Cast Nets	19,294	$8,179	$2,244	$0.42	$0.12		Cast Nets	29,873	$12,765	$3,098	$0.43	$0.12
	Other Gears	71,563	$67,645	$18,555	$0.95	$0.27		Other Gears	24,399	$11,197	$2,718	$0.46	$0.13
	Total	2,298,240	$1,943,834	$533,194	$0.85	$0.24		Total	2,829,075	$1,592,056	$386,392	$0.56	$0.16
1996	Gill Net Set	786,454	$464,140	$123,647	$0.59	$0.17	2001	Gill Net Set	831,345	$400,543	$94,528	$0.48	$0.14
	Gill Net (Runaround)	879,170	$573,005	$152,648	$0.65	$0.18		Gill Net (Runaround)	1,344,935	$705,309	$166,453	$0.52	$0.15
	Seines	42,467	$33,166	$8,835	$0.78	$0.22		Seines	96,939	$53,431	$12,610	$0.55	$0.16
	Cast Nets	17,244	$8,123	$2,164	$0.47	$0.13		Cast Nets	25,725	$10,355	$2,444	$0.40	$0.11
	Other Gears	31,165	$20,765	$5,532	$0.67	$0.19		Other Gears	18,711	$8,726	$2,059	$0.47	$0.13
	Total	1,756,500	$1,099,198	$292,826	$0.63	$0.18		Total	2,317,655	$1,178,364	$278,094	$0.51	$0.14
1997	Gill Net Set	1,017,497	$677,557	$176,436	$0.67	$0.19	2002	Gill Net Set	927,511	$432,696	$100,559	$0.47	$0.13
	Gill Net (Runaround)	1,150,388	$891,953	$232,264	$0.78	$0.22		Gill Net (Runaround)	1,349,238	$677,882	$157,540	$0.50	$0.14
	Seines	201,940	$162,519	$42,320	$0.80	$0.23		Seines	249,957	$117,393	$27,282	$0.47	$0.13
	Cast Nets	25,394	$11,429	$2,976	$0.45	$0.13		Cast Nets	37,491	$15,704	$3,650	$0.42	$0.12
	Other Gears	46,792	$33,870	$8,820	$0.72	$0.20		Other Gears	31,778	$14,382	$3,342	$0.45	$0.13
	Total	2,442,011	$1,777,328	$462,816	$0.73	$0.21		Total	2,595,974	$1,258,058	$292,373	$0.48	$0.14
1998	Gill Net Set	899,409	$415,695	$106,584	$0.46	$0.13							
	Gill Net (Runaround)	1,097,592	$543,192	$139,274	$0.49	$0.14							
	Seines	150,450	$74,227	$19,032	$0.49	$0.14							
	Cast Nets	27,792	$11,772	$3,018	$0.42	$0.12							
	Other Gears	42,830	$21,302	$5,462	$0.50	$0.14							
	Total	2,218,073	$1,066,188	$273,371	$0.48	$0.14							

7.2.3 Marketing, Distribution, and Processing

From 2000 to 2002, approximately 200 to 210 dealers purchased striped mullet from fishermen (Table 7.2). While the number of dealers did not change much in these years, the number of dealers who purchased less than 100 pounds from fishermen increased, while the number of dealers who purchased more than 15,000 pounds from fishermen decreased.

Table 7.2. Number of dealers and the number of pounds purchased of striped mullet from 2000 to 2002 (DMF Trip Ticket Program).

	Year		
	2000	2001	2002
Less than 100 pounds	15	22	42
100 to 500 pounds	30	35	37
500 to 1,000 pounds	22	20	15
1,000 to 5,000 pounds	53	51	47
5,000 to 15,000 pounds	37	34	30
More than 15,000 pounds	53	48	30
Total dealers	210	210	201

Approximately 60% of all striped mullet are landed in the fall months during roe season. In past years, a few large processors bought large amounts of these roe mullet and took them as fresh whole fish to Florida for processing. Currently, there is only one large processor buying the bulk of the roe mullet landings. Once at the processor, the roe is extracted from the fish where it is primarily destined for Asian markets where it is sold for food and medicinal purposes. The remaining fish is filleted, frozen, and shipped overseas, primarily to Egypt and other African countries for human consumption. Striped mullet roe is also a local delicacy in some parts of coastal North Carolina where it is dried to preserve it for later consumption. Seafood markets in areas where striped mullet is landed frequently sell the meat and roe to local customers. During the non-roe season, striped mullet is sold as bait, or fresh for human consumption.

7.2.4 Economic Impact of Commercial Fishing

In 2001, striped mullet landings accounted for 2.4% of all the pounds and 3.3% of the total value of finfish landed in North Carolina. When Atlantic menhaden landings were removed, striped mullet accounted for 5.5% of all the pounds and 3.8% of the total value of finfish landed in North Carolina.

Table 7.3 shows the number of participants in the fishery by year and the value of their annual landings for 1994 through 2002. Over 1,000 participants took part in the striped mullet fishery in each year, however there were fewer participants in each successive year. It is likely that lower dockside prices paid to fishermen account for the decreasing number of annual participants in the fishery.

Approximately half of the participants were paid less than $100 for striped mullet they landed in each of the years 1994 to 2002. Three to seven percent of the fishermen made more than $5,000 from the fishery in each of these years.

Table 7.3. Number of participants in the striped mullet fishery by year and value (unadjusted for inflation) of annual striped mullet landings: 1994 –2002 (DMF Trip Ticket Program).

	Year								
	1994	1995	1996	1997	1998	1999	2000	2001	2002
Up to $100	787	723	734	655	623	521	610	541	526
$100 to $500	273	298	311	306	276	216	242	226	217
$500.01 to $1,000	96	124	142	136	82	77	108	89	77
$1,000.01 to $2,000	98	109	102	108	83	72	97	72	79
$2,000.01 to $5,000	70	111	94	117	73	76	89	67	74
$5,000.01 to $10,000	27	52	28	57	30	16	38	47	29
$10,000.01 to $20,000	10	26	8	24	12	9	32	23	22
More than $20,000	5	14	4	8	4	5	9	4	8
Total participants	1,366	1,457	1,423	1,411	1,183	992	1,225	1,069	1,032

Table 7.4 shows the economic impact of commercial fishing for striped mullet to the State of North Carolina. These impacts were calculated using the number of persons harvesting striped mullet and the value of those landings (IMPLAN 2000). The numbers provided can be considered to be an underestimate of the total impact because there are no data available that accurately describe the business to business cash flow between commercial fishermen and those who provide services to them. However, the impacts do include the added value to the economy by commercial fishermen based on their spending just from the money they received for the annual catch of striped mullet. The multiplier shown for each year is a mathematical representation of the additional value of the striped mullet as it moves through North Carolina's economy. The annual impact of striped mullet on the North Carolina economy is approximately $1.9 to $2.6 million in the years 2000 to 2002.

Table 7.4. Economic impact of striped mullet fishing to the economy of North Carolina: 2000 – 2002 (unadjusted for inflation).

Year	Value	Impact	Multiplier
2000	$1,592,056	$2,594,986	1.63
2001	$1,178,364	$1,920,549	1.63
2002	$1,258,058	$2,050,551	1.63

In 2001, a self-reported socioeconomic survey of Core Sound area commercial fishermen and seafood dealers based on their 2000 fishing activities was conducted by the DMF (Cheuvront, 2002). Fifty-nine fishermen who participate in the striped mullet fishery were interviewed. Approximately seven percent of the fishermen reported that they had no profit from their fishing operation in 2000. Approximately half of the fishermen could be considered part-time fishermen. On average, these fishermen earned between $1 and $15,000 from all their fishing activities. A few reported they lost money because their expenses outweigh their income from fishing. The full time fishermen were most likely to earn between $15,000 and $30,000 from fishing with a few earning more.

7.3 RECREATIONAL FISHING

There are two survey programs in North Carolina that collect data from recreational striped mullet fishermen. The Marine Recreational Fisheries Statistics Survey (MRFSS) collects data from the ocean landings 0 – 3 miles from the coast and inside waters from south of the Albemarle Sound to the South Carolina border. In 2002, the DMF began collecting data from recreational fishermen

(RCGL) who are licensed to use limited amounts of commercial gear.

7.3.1 Historical Trends in Landings

MRFSS. The Marine Recreational Fisheries Statistics Survey (MRFSS) provides coverage of saltwater sport fishing (including estuarine and brackish water) from private/rental boats, charter and head boats, manmade structures, and the shore throughout North Carolina.

MRFSS data is collected by two independent, but complementary, surveys; 1) a telephone survey of households in coastal counties, and 2) an intercept (i.e. interview) survey of anglers at fishing access sites. Catch data are obtained from anglers intercepted by creel clerks stationed at fishing access sites. In North Carolina, access sites are recognized as any site where the likelihood of encountering marine species may exist. These sites do not extend much farther inland than the boundaries established for the coastal zone.

Striped mullet are landed by recreational anglers primarily for bait and are caught using small nets such as cast nets. While the MRFSS primarily targets hook and line anglers, data are collected on these catches because they relate to a recreational fishing trip.

The majority of people landing striped mullet in North Carolina were residents of the State. About 15 % were from Virginia. The remaining 12% of anglers were from other states (Table 7.5).

Table 7.5. State of residency of anglers landing striped mullet (NC MRFSS).

State	Frequency	Percent
North Carolina	243	73.0
Virginia	50	15.0
Maryland	13	3.9
Pennsylvania	8	2.4
New York	4	1.2
Other states	15	4.5

RCGL. In 2002, the DMF began interviewing recreational fishermen who have purchased a license that allows them to use limited amounts of commercial gear. These fishermen are prohibited from selling their catch as it is intended solely for personal use. Specific monthly or bimonthly landings data were collected beginning in January 2002.

The months of October, July, and August of 2002 accounted for over 50% of the total harvest by RCGL holders. Gill nets were the only gears recorded used by RCGL fishermen for targeting striped mullet.

7.3.2 Recreational Fishing Activity

MRFSS recreational anglers target striped mullet primarily as bait to catch other species of fish. Table 7.6 indicates the disposition of the striped mullet. Nearly 60% were used as bait. The 19% that were released alive were probably caught in a cast net and intended for use as bait, but were not needed. Anglers planned to consume the remaining 21%.

Table 7.6. Disposition of striped mullet landings by recreational anglers in North Carolina, 1992 – 2001 (NC MRFSS).

Disposition	Percent
Thrown back alive	19.0
Eaten/plan to eat	21.1
Used for bait/plan to use for bait	59.9

The RCGL holder surveys did not specifically determine the final disposition of the striped mullet landed by these anglers. However, it is presumed they use the fish primarily as bait for other species, or for harvesting roe. Drying mullet and their roe for later consumption is popular with some coastal North Carolina residents.

RCGL holders made nearly 10,000 trips in 2002 in which they caught striped mullet. The months of June, August, September, and October accounted for nearly two thirds of all RCGL trips landing striped mullet in 2002 (Table 7.7).

Table 7.7. Estimated number of striped mullet trips taken by RCGL fishermen in 2002 (DMF RCGL Survey Program).

Month	Estimated number of trips
January/February	231
March/April	1,256
May	665
June	1,359
July	865
August	1,403
September	1,281
October	1,988
November	840
December	97
Total for 2002	9,985

7.3.3 Economic Value of the Recreational Fishery

Table 7.8 gives an indication of the economic impact of the recreational striped mullet fishery by RCGL fishermen in 2002. The data are separated by those who made overnight trips as opposed to those who made day trips. The economic figures are based on an expansion of the actual values reported by RCGL fishermen and are considered the best available estimates. The economic impacts described below are those that can be attributed only to striped mullet landings by these fishermen. In many, if not most of the out of town trips, the fishermen and the non-fishers who accompanied them, engaged in other, non-fishing activities.

The expenditures shown in table 7.8 relate to the overall proportion of striped mullet landed. Other species were typically caught along with the striped mullet. The economic impact was based on the percent of striped mullet in the total pounds of all species kept by the fishermen on any given

trip where striped mullet were landed. The total pounds of striped mullet landed were 64,213.03 pounds out of a total 287,213.21 pounds landed and kept. Striped mullet accounted for 22.36% of the total catch on trips in which striped mullet were landed.

Expenditures by those who made overnight trips tend to be greater when compared to day trips because of the increased costs of lodging and meals. An average overnight trip lasted approximately 3 days and resulted in total expenditures of $260.50, however, only $33.20 were attributable to striped mullet landings. The total economic impact of overnight RCGL trips for just striped mullet was $131,074. The average expenditures for day trip fishermen were approximately $44.44, with $6.16 attributable to striped mullet landings. The total economic impact of striped mullet caught on day trips for was $37,182. The total combined economic impact of all RCGL trips for just striped mullet in 2002 (and the non-fishers accompanying them) was approximately $168,256.

Table 7.8. Economic impact of RCGL fishing trips for striped mullet in 2002 (NC DMF RCGL Survey Program).

	Overnight trips	Day trips
# of trips taken	3,948	6,036
Avg. # of nights	3	N/A
Avg. # of people on the trip	4.9	4.2
% of people on trip who fished	57%	62%
Avg. cost of lodging/night	$59.12	N/A
Avg. cost of food/trip	$46.22	$19.17
Avg. cost of fuel & oil/trip	$36.92	$25.27

7.4 DEMOGRAPHIC CHARACTERISTICS

7.4.1 Commercial Fishermen

Sociodemographic data were collected from 59 Core Sound area commercial fishermen who reported they had targeted striped mullet during 2000 (Cheuvront, 2002). Table 7.9 shows a summary of the demographic characteristics of the striped mullet fishermen used in this analysis. Nearly all of the striped mullet fishermen were white males. They averaged 49 years old and had over 26 years fishing experience. The average striped mullet fisherman was currently married and had a high school diploma or less education. Approximately an equal number of fishermen had total household incomes of $15,000 to $30,000, as had total household incomes of $30,001 to $50,000.

Table 7.9. Demographic characteristics of striped mullet fishermen who participated in the Core Sound fisherman survey, (Cheuvront, 2002).

n=59		Average or percent
Years fishing		26.5
Age		48.8
Gender	Male	98%
	Female	2%
Race	White	98%
	Hispanic	2%
Education level		
	Less than High School	31%
	High School graduate	39%
	Some College	20%
	College graduate	10%
Marital status		
	Married	83%
	Divorced	10%
	Widowed	3%
	Never married	2%
	Separated	2%
Total household income		
	less than $15,000	12%
	$15,001 - $30,000	31%
	$30,001 - $50,000	29%
	$50,001 - $75,000	14%
	$75,001 - $100,000	7%
	Refused to answer	9%

Like most of North Carolina's full- and part-time commercial fishermen, nearly all of these 59 fishermen also targeted other species at other times during the year. Only one of these fishermen used a beach seine as opposed to a gill net for landing striped mullet. On average, these fishermen earned 47% of their total fishing income from gill net fishing. Some striped mullet fishermen target other species using gill nets. Fourteen percent of the fishermen also targeted spot and 33% targeted flounder. Additionally, 20% of these fishermen also trawled for shrimp, 17% said they also fished crab pots, and 19% stated they also have a valid North Carolina fish dealer's license.

Approximately 56% of the fishermen interviewed said they fished all year long. Of those who

didn't fish all year, fishing activity was lowest from December through March. The peak fishing participation months for these fishermen were August through November.

Fifty-nine percent of the striped mullet fishermen in this study did not earn all of their individual income from fishing. The most frequently cited sources of additional income included carpentry, machinery mechanic, government, and retirement pensions.

Nearly 92% of the fishermen owned their fishing operation as a sole proprietorship. The average boat was 22 ft. long, was 10 years old and had a current market value of just under $16,000. The average striped mullet fishermen (including full and part time) earned just under $13,000 profit from all of their fishing activities. They averaged $54.55 for routine fishing trip costs (fuel, ice, groceries, etc.). In 2000, they averaged nearly $5,000 in fixed business costs (new equipment, repairs, business loan payments, etc.).

These fishermen were asked to state the business issues they found to be the most important they were currently facing. Nearly a quarter of them stated that low prices for seafood was the most important issue, followed closely by a feeling that there are too many regulations affecting their ability to fish. An additional 13% expressed difficulties in keeping up with changes in proclamations and rules as the major issue. The next most important issues in order were overfishing and gear restrictions. Several other issues were mentioned as being extremely important, but were not selected by more than two or three other fishermen: bag limits, weather, environmental regulations, closed areas (for those who also shellfished), seasonal closures, inability to predict the future of the industry, and outside competition.

7.4.2 Recreational Fishermen

Sociodemographic characteristic estimates of MRFSS anglers targeting or catching striped mullet would be unreliable as the number of observed MRFSS trips was quite low. Data were collected from 770 individuals who said they had targeted striped mullet on at least one RCGL fishing trip in 2001.

The average RCGL holder who targeted striped mullet was 55.8 years old and had lived in North Carolina for over 49 years (Table 7.10). The vast majority were males. Most of these anglers had at least some college education and had total household incomes of greater than $30,000 per year. On average, they had been using commercial gear for 22.6 years.

Table 7.10. Sociodemographic data of RCGL holders who targeted striped mullet in 2001. (NC DMF RCGL Survey Program).

Demographic	Category Values	Sample Size	Average/ Percent
Years Experience Fishing Commercial Gear		745	22.6
Born in NC		770	89%
Years Lived in NC		682	49.1
Age		773	55.8
	< 16 years	3	0.38%
	17 to 25	11	1.42%
	26 to 40	96	12.42%
	41 to 60	352	45.53%
	> 60 years	311	40.23%
Marital Status		769	
	Married	661	86%
	Divorced	38	5%
	Widowed	31	4%
	Separated	8	1%
	Never Married	31	4%
Ethnic Group		770	
	Hispanic/Latino	1	0.13%
	Caucasian/White	721	93.64%
	African-American/Black	5	0.65%
	Native American	43	5.58%
Gender		762	
	Male	723	94.88%
	Female	39	5.12%
Education		764	
	< HS	109	14.27%
	HS Diploma	235	30.76%
	Some College	253	33.12%
	College Diploma	167	21.89%
Total Household Income		688	
	< $5,000	6	0.89%
	$5,000 to $15,000	32	4.60%
	$15,001 to $30,000	138	20.03%
	$30,001 to $50,000	194	28.19%
	$50,001 to $75,000	166	24.18%
	$75,001 to $100,000	79	11.42%
	> $100,000	73	10.68%

8. ENVIRONMENTAL FACTORS

8.1 HABITAT

Striped mullet habitat use varies greatly based on life history stages, seasons, and location (Able and Fahay 1998; Pattillo et al. 1999; Cardona 2000). Salinity seems to play a major role on habitat utilization and distribution of both adult and juvenile mullet (Cardona 2000). They are a highly euryhaline fish and live in a wide range of salinities, based on size and maturity (Pattillo et al. 1999; Cardona 2000). The availability of suitable food may also influence habitat use by striped mullet (Moore 1974). They are found in almost all shallow marine and estuarine habitats including beaches, tidal flats, lagoons, bays, rivers, channels, marshes and grassbeds (Moore 1974; Pattillo et al. 1999; Nordlie 2000). They can be found in depths ranging from a few centimeters to over 1,000 m but are mostly collected within 40 m of the surface. Once in inshore waters they prefer depths of 3 meters or less.

Ocean Water Column. Striped mullet spawn in warm saline offshore waters then move to cooler, less saline coastal waters (Powles 1981). Striped mullet begin to spawn offshore in the South Atlantic Bight continental shelf waters from the 36 m line into the Gulf Stream when water temperatures begin to fall (Able and Fahay 1998). Larvae and small juveniles have been collected over the outer half of the shelf during winter. Fahay (1975) captured juveniles near the Gulf Stream off the North Carolina coast in January. However, these juveniles were probably subject to advection currents, moving them north into Middle Atlantic Bight waters. Powles (1981) found an inverse relationship of larval length to distance from shore. Pelagic juveniles begin shoreward movement via Ekman currents once they are between 20-25 mm in length. These larvae arrive along barrier beaches in November and stay along these areas through April (Powles 1981). Once nearshore, larvae must pass through inlets to reach estuarine nursery areas. The inlets are therefore a critical component of the water column habitat for striped mullet, as well as other offshore spawners. Peters et al. (1995) documented striped mullet larvae in Beaufort Inlet between October and April, but in relatively low numbers compared to other species. Jetties potentially threaten successful recruitment since they can obstruct inlet passage (Blanton et al. 1999).

Ocean Beaches. Juvenile striped mullet utilize ocean waters adjacent to sandy beaches and in the surf zone in the Gulf States and along North Carolina's coast (Ross and Lancaster 2002). Perry and Carter (1979) sampled three beach stations located on the southwest coast of Louisiana over a period of six and a half years. These beach areas were composed of fine sands mixed with broken shell. Striped mullet were the third most abundant species taken during the study with the majority taken in January. Both juvenile and adult striped mullet (12-335 mm) were captured using a bag seine pulled parallel to each beach site. Striped mullet are also found in beach habitats as well as estuarine habitats in Texas (Moore 1974). The surf zone of sandy beaches in Japan is considered a transient habitat, orienting fish larvae to the estuaries (Kinoshita 1988 in Fujita et al. 2002). Threats to ocean beaches and surf zone include beach nourishment and stormwater outfalls.

Wetlands. Salt and brackish marshes are tidal wetlands, usually located in low energy environments such as sounds, bays and rivers where salinity is greater than 0.5 ppt. They are a complex habitat influenced by tide, salinity, temperature and nutrients. Salinity in the marsh can vary because of evaporation and mixing of seawater and freshwater. It is a stressful environment for both plants and animals because of changes that occur in these variables. However, it is considered one of the most biologically productive ecosystems in the world. The high primary productivity that occurs in the marsh and the transfer of detritus into the estuary from the marsh provides the base of the food chain supporting many marine organisms including the striped mullet. Overall, North Carolina has approximately 212,800 acres of marsh habitat and is second to South Carolina in total acreage in the

South Atlantic. In North Carolina, these salt marsh habitats are important nursery areas for striped mullet, as well as many other fish and invertebrate species (Weinstein 1979).

The striped mullet is considered a transient estuarine fish because they spend a portion of their life cycle (juvenile stage) in estuarine rivers and marshes (Kneib and Wagner 1994; Peterson and Turner 1994). Recent work in Texas by Rozas and Zimmerman (2000) found that striped mullet preferred low elevation marsh edges to high elevation marsh. Kneib and Wagner (1994) found that striped mullet abundance was highest in the low marsh during incoming and slack high tide. Work by Peterson and Turner (1994) showed that striped mullet used marsh edge surface (<3m from creek) even though juvenile mullet were observed in the interior of marshes during deep flood tides. While the majority of research shows striped mullet prefer marsh edge, other studies have indicated that striped mullet also utilize interior marshes (Peterson and Turner 1994). Kneib and Wagner (1994) also found a preference by striped mullet for inner *S. alterniflora* over *Scirpus* marsh found in similar elevations.

Wetlands are threatened by many human activities, including dredging for marinas and channels, filling for development, ditching and draining for agriculture, silviculture, and development, channelization, and shoreline stabilization. These threats and how they alter the functions of wetlands are discussed in detail in the Coastal Habitat Protection Plan (CHPP).

Soft Bottom. Soft bottoms are the unconsolidated, unvegetated sediment covering the bottom of freshwater, estuarine and marine systems. There are many different types of soft bottom in coastal North Carolina, including intertidal, shallow, and deep bottom sediments in lakes, freshwater creeks, rivers (Chowan, Roanoke, Tar/Pamlico, Neuse, Cape Fear), estuarine creeks, (Pamlico River, lower Neuse River, Albemarle Sound), sounds (Pamlico, Core and Bogue sounds), beaches, and the seafloor. These estuarine soft bottoms provide nursery area habitat, food and refuge from large predators.

Soft bottom plays an important role in the life cycle of the striped mullet. Soft bottom habitat is a key source of food for striped mullet throughout its life cycle. During the larval stage, striped mullet are planktonic, macrophagous, carnivores feeding on zooplankton like diatoms, copepods, and mosquito larvae until they reach sizes between 20 to 30 mm. At this point, their feeding ecology changes to benthic, microphagous, omnivory, eating organic detritus, filamentous algae, plant tissue, diatoms, and benthic microorganisms (Blaber and Whitfield 1977; Collins 1985; Pattillo et al. 1999). Soft bottom sediments produce benthic microalgae, microscopic photosynthetic algae, on their surfaces, which striped mullet forage on. These benthic microalgae, primarily composed of benthic diatoms and blue green algae, are the base of the food chain (Peterson and Peterson 1979; Miller et al. 1996). Benthic microalgae support small benthic invertebrates that live in the sediment. Detrital matter from other habitats such as tidal marsh and SAV drifts away and settles on intertidal flats, shorelines, and shallow soft bottoms, where it can be broken down and consumed by striped mullet (Peterson and Peterson 1979). Benthic microalgae, detritus, and small invertebrates are all important food sources utilized by striped mullet. The organic matter produced or imported onto soft bottom sediments can also be resuspended under certain environmental conditions, where it becomes available to larval striped mullet and other organisms in the water column.

Structure. Structure may also play a role as habitat for striped mullet. DMF field staff that sample for striped mullet in rivers and creeks find schools around structure such as fallen trees and grassbeds. Fishermen have stated that they search for mullet schools around piers and docks and often capture fish adjacent to these structures. Striped mullet also inhabit prop root habitat of the red mangrove in Everglades National Park (Thayer et al. 1987).

Seagrass meadows are a complex ecosystem that provide structural complexity and are the preferred habitat for many species of finfish and crustaceans. There are approximately 200,000 acres of seagrasses in North Carolina consisting of three species of seagrasses in North Carolina. They are the shoal grass (*Halodule wrightii*), eel grass (*Zostera marina*) and widgeon grass (*Ruppia maritima*) and are present throughout the year from the northern part of the State southward through Bogue Sound. Work in Florida Bay indicates that striped mullet move on and off seagrass-covered mud banks at dawn and dusk with greatest capture at low tide. At high tide, the fish would occupy the top of the bank and move toward the edge as the tide receded, leaving the bank only at the lowest water levels (<10cm) then returning as water level begins to rise (Sogard et al. 1989). Mullet will also feed on epiphytes and epifauna from seagrasses and other structures (Collins 1985a). There is very little information about the use of SAVs by striped mullet in North Carolina however anecdotal observations from independent sampling by DMF staff might indicate habitat preference for seagrass structure.

Clearing of woody debris from streams reduces the complexity and structure of the shoreline. Grass beds are threatened by physical destruction from bottom disturbing fishing ear, dredging, and damage from boat use, as well as degradation of water quality.

8.2 WATER QUALITY

Salinity. Striped mullet live in salinities ranging from 0.0 parts per thousand (ppt) to 75.0 ppt but prefer a median range of 20.0 ppt to 26.0 ppt (Collins 1985a, Leard et al. 1995; Pattillo et al. 1999). Size plays a role in the osmoregulation capabilities of the mullet. Larvae are very stenohaline (25.0 ppt to 35.0 ppt), and with growth become more tolerant of a wider range of salinities (freshwater to 35.0 ppt). Striped mullet can fully osmoregulate by the time they reach a standard length of 40-69 mm, at an age of approximately 7 to 8 months old (Collins 1985a; Pattillo et al. 1999).

Temperature. As with salinities, striped mullet are able to live in a wide range of temperatures from 5.9^{o} C. to 37.0^{o} C. Optimal egg and larval development occur at 21.0^{o} C. to 24^{o} C. (Pattillo et al. 1999). Preferences by juveniles and adults range from 20^{o}C to 30^{o}C and 16^{o}C to 30^{o}C, respectively (Pattillo et al. 1999).

Dissolved Oxygen. Striped mullet have the ability to tolerate low levels of dissolved oxygen (DO). They have enhanced hemoglobin concentrations that allow them to meet seasonally heavy oxygen demands during warm summer months and the autumn spawning period. They also have the ability to capture air in the upper posterior portion of the pharynx by jumping, rolling or holding the head above water and moving it into the upper pharyngeal chamber to supplement their oxygen supply for respiration (Pattillo et al. 1999).

Water Quality Degradation

Human Population Growth. Good water quality in North Carolina's estuaries is essential to the striped mullet population because of its estuarine dependent lifestyle. Striped mullet spend the majority of their lifetime in estuarine waters with the exception of a brief larval stage in offshore waters as well as yearly fall migrations to the ocean to spawn. There have been significant population increases over the past 20 years in several watershed basins that drain into our estuaries such as in the White Oak River Basin (NCDENR 2001) Lumber River Basin (NCDENR 1999), and Neuse River Basin (NCDENR 2002). This increase in population, especially in the coastal regions of these basins causes generation of increased stormwater runoff, the addition of new septic tanks, the need for more wastewater treatment capacity, a need for new and expanded water supply sources, and the location of new marinas (NCDENR 2001). These population impacts on water quality can vary dependent on

development locations, land use and topography of the river basin (CHPP 2004).

There are two primary sources of pollution, nonpoint and point source. Point source pollution is defined as pollution from a defined point such as a pipe while nonpoint source pollution is pollution from a non-defined point of entry such as stormwater run off. Both source types contribute to oxygen consuming wastes, nutrients, sediment, as well as toxins, pesticides, and heavy metals. Point source dischargers (municipal and industrial wastewater treatment plants, small domestic wastewater treatment system for schools, commercial offices, residential subdivisions and individual homes) in North Carolina must apply for and obtain a National Pollutant Discharge Elimination System (NPDES) permit from the Division of Water Quality (NCDENR 2000).

Sediment and nutrients are the major pollution substances associated with nonpoint source pollution but fecal coliform bacteria, heavy metals, oil and grease as well as any substance that may be washed from the ground or removed from the atmosphere also result from nonpoint sources. Several activities are associated with non point source pollution. These include land clearing, plowing, drainage ditch construction, pesticide and fertilizer use, as well as concentrated livestock operations (NCDENR 2000).

Nutrients. Nitrogen and phosphorus (components of fertilizers) and animal and human wastes are referred to as nutrients. These elements, in small quantities, are beneficial to aquatic life but can be detrimental in large quantities. In excessive amounts, nutrient loading leads to habitat degradation, toxicity, hypoxia, anoxia, algal blooms, fish kills, and loss of biodiversity (Paerl 2002). These are all signs of cultural eutrophication and water quality degradation (NCDENR 2000; Paerl 2002). Cultural eutrophication is the rapid process of the accumulation of nutrients and sediments caused by man (NCDENR 2000). Urban runoff, crop agriculture, animal operations, erosion, and industrial expansion in the coastal regions have lead to the rise of nitrogen loading in our estuaries.

Atmospheric depositions of nitrogen (AD-N) used to be considered a minor source of nitrogen input. However, recent research has shown this nitrogen input to be a highly significant source of externally supplied nitrogen entering the estuaries (Paerl 2002). There also may be a link between acidic deposition (acid rain) and eutrophication of estuaries (Driscoll et al. 2003). Sources of both AD-N and acid rain are mostly from burning fossil fuels and by agricultural activities (Paerl 2002; Driscoll et al. 2003).

Dinoflagellate algal blooms have been known to occur from nutrient over enrichment and can be detrimental to marine life since some may be toxic. Fish sampling by DWQ, DMF and NCSU was initiated in 1998 in the Neuse, Tar-Pamlico, and New rivers to determine the occurrence of and species impacted by these toxic dinoflagellates including *Pfisteria piscicida*. The predominant fish affected with lesions was the Atlantic menhaden (*Brevoortia tyrannus*). Less than 0.1% of striped mullet sampled showed any sign of lesions.

The first record of the toxic dinoflagellate *Gymnodinium breve* bloomed in North Carolina in 1987. Larval recruitment of striped mullet was low during the bloom but increased significantly later in the season, suggesting that there were immediate effects (Warlen et al. 1998). Another dinoflagellate *Gymnodinium pulchellum* was responsible for fish kills in the Indian River, Florida in October 1996 and had an effect on striped mullet (Steidinger et al. 1998).

Anthropogenic alterations have been shown to cause declines in striped mullet populations in some regions. For example, in a lake in Egypt, salinities have declined and nutrient load has increased from agricultural drain water inflows, reduced evaporation due to reduction of lake areas, and increased sewage outfall from Cairo. These impacts of degrading water quality caused a decline in the mullet fishery from 65 percent of the total catch during the 1920s to only 2.2 percent during the

early 1980s (Khalil 1997).

Oxygen Depletion. Oxygen depletion, or anoxia (no oxygen) and hypoxia (low oxygen), can occur naturally from stratification of the water column caused by wind, temperature and salinity conditions. However, nutrient over enrichment also leads to anoxia and/or hypoxia. Increased runoff and organic loading from heavy rainfall will cause hypoxic and anoxic events. Algal blooms mentioned above remove dissolved oxygen (DO) from the water at night (no photosynthesis). When these blooms die, bacteria decomposing the dead plant material remove oxygen. Although algal blooms occur naturally under undisturbed conditions, additional nutrient inputs caused by man increase their frequency and intensity.

Several hurricanes occurring in September and October of 1999 significantly impacted water quality in North Carolina. Because of the heavy rainfall, in short time periods during these storms, record flooding caused an input of at least half of the typical nitrogen load, as well as twice the amount of carbon input into Pamlico Sound through the Neuse River. This heavy pulse of nutrients and freshwater runoff caused bottom water hypoxia, an increase in algal biomass for a long period, and the displacement of many marine organisms as well as an increase in the occurrence of fish disease (Paerl et al. 2001).

One commonly observed effect of anoxia and hypoxia are fish kills. Low oxygen is considered the leading cause of fish kill events in 22 coastal states (Lowe et al. 1991). There were 46 fish kill events in 2002, reported to DWQ, of which 16 were estuarine. Three of these events recorded the presence of mullet. Poor dissolved oxygen was cited as the cause of 33% of the total number of fish kills for the year with algal blooms being the cause of seven percent. However, unlike previous years, the majority of these occurred in fresh water where the drought conditions had caused low water flow and high water temperatures (NCDENR 2002).

Fish can move from hypoxic areas and seek more oxygenated waters. Any consequences suffered by fish because of low DO depend on their ability to detect and avoid low DO areas. Wannamaker and Rice (2000) found that white mullet could detect and respond to hypoxic events and avoid areas of 2.0 mg O_2/liter or less. Mullet appeared to be more sensitive to moderate hypoxia than both spot and pinfish. Mullet also showed higher ventilation rates. These high ventilation rates demonstrate that hypoxia may cause greater respiratory distress and may explain why they avoid hypoxic zones.

Turbidity and Sedimentation. Another natural process that occurs in our estuaries is erosion and sedimentation. Both processes occur when waves and currents erode shoreline and transport sediment into the waters, causing short and long-term changes along the coast. However, this process, like eutrophication has been accelerated because of man's activities. Sediment loading usually results from non-point sources such as building and road construction. Stormwater runoff from urban areas, agriculture, silviculture, animal operations, as well as mining and removal of vegetated buffers accelerates sediment loading as well as increases turbidity in the water column (NCDENR 2000). Water activities such as dredging, boating and fishing with bottom disturbing gears also adds to an increase in turbidity. Of all of these sources, agriculture is one of the largest contributors of sedimentation in the southeastern US (SAFMC 1998)

Sediment impacts on fish depend on the concentration of sediment, type of sediment, and the duration of the sedimentation. These impacts can plug gills and reduce respiratory abilities. This can lead to a reduced tolerance to disease, toxins and turbidity (NCDENR 2000). Other effects include the alteration of habitats that can effect spawning, and rearing habitat (NCDENR 2000).

Toxic chemicals. Toxic chemicals that are found in the water column include heavy metals,

polycyclic aromatic hydrocarbons (PAHs), petroleum hydrocarbons, polychlorinated biphenyls (PCBs), dioxins, antifoulants, chlorine, ammonia and pesticides. Most of these chemicals come from localized point and nonpoint sources while activities contributing to heavy metal contamination include urban sprawl, dock and marina development, boating activity, dredge spoil disposal, automotive transportation, industrial shipping and industrial emissions (Wilbur and Pentony 1999). Studies have shown that fine-grained sediments act as a reservoir for heavy metals and are readily adsorbed on tiny sediment particles, particularly organic rich muds (Riggs et al. 1991). Chemicals such as DDT, Diedrin and TBT continue to contaminate sediments, even though they have been banned since 1977. Resuspension of sediments with heavy metal contamination can be a problem in fine-grained areas such as sheltered creeks. Because low concentrations of heavy metals in the water column can be easily incorporated into fine-grained sediment, such as organic rich mud, toxicants levels can accumulate in the sediment and be resuspended into the water column (Riggs et al. 1991). This is of particular concern as the majority of North Carolina's primary nursery areas are composed of fine-grained sediments located in headwaters of various waterbodies.

Hackney et al. (1998) surveyed 165 sites within North Carolina's sounds and rivers during 1994-1997 to evaluate environmental conditions as part of the USEPA Environmental Assessment Program. Highest contamination levels occurred in low salinity areas with low flushing and high river discharge. Benthic populations were dominated by tolerant opportunistic species and had low species richness. It was estimated that 13.4 percent of the estuarine bottoms were incapable of supporting benthic production. Contaminants surveyed included nickel, arsenic, DDT, PCBs, and mercury. The investigation found that 37.5% to 75.8% of the randomly selected stations had contaminated surface sediment, and 19% to 36% of the sites were highly contaminated. Fish sores and lesions were more prevalent at sites with high sediment contamination (up to 50% of examined fish), but sores were also found at less contaminated sites. Laboratory bioassays showed that sediments from many sites were toxic to biological organisms. Riggs et al. (1980) and Riggs et al. (1991) assessed concentrations of heavy metals in the Neuse and Pamlico estuaries. In the Neuse River, surface sediments were found to be elevated with several heavy metals, including zinc, copper, lead, and arsenic and 17 areas between New Bern and the mouth of the river were identified as "contaminated areas of concern". The contaminated sites were primarily attributed to permitted municipal and industrial treatment plant discharges. Marinas were also found to contribute substantial amounts of copper and variable amounts of zinc and lead. Non-point sources were more difficult to evaluate. In the Pamlico River, heavy metal contamination was less severe, although arsenic, cobalt, and titanium exceeded the levels found in the Neuse River. These studies suggest that sediment contamination in some estuarine areas; especially those where both organic rich mud and wastewater discharges are present, may be significant and could affect fish populations and the base of their food chain.

Habitat and Water Quality Protection

Authority. Presently, the MFC has authority for the following actions with regard to marine and estuarine resources: manage, restore, develop, cultivate, conserve, protect, and regulate. Marine and estuarine resources are "All fish [including marine mammals, shellfish, and crustaceans], except inland game fish, found in the Atlantic Ocean and in coastal fishing waters; all fisheries based upon such fish; all uncultivated or undomesticated plant and animal life, other than wildlife resources, inhabiting or dependent upon coastal fishing waters; and the entire ecology supporting such fish, fisheries, and plant and animal life." (G.S. 113-129)

The MFC has the power and duty to: authorize, license, regulate, prohibit, prescribe, and restrict: All forms of marine and estuarine resources in coastal fishing waters with respect to: (1) Time, place, character or dimensions of any method or equipment that may be employed in taking

fish, (2) Season for taking fish, and (3) Size limits on and maximum quantities of fish that may be taken. Possession, cultivation, transportation, importation, exportation and sale of all marine and estuarine resources and all related equipment and vessels is also under the authority of the MFC.

The MFC also has authority to comment on State permit applications that may have an effect on marine and estuarine resources, regulate placement of fishing gear, develop and improve mariculture, regulate location and utilization of artificial reefs, and regulate the disposition of the young of edible fish. MFC authority is found in G.S. 143B-289.51 and 289.52

Authority of Other Agencies. The North Carolina Division of Coastal Management (DCM) is responsible for development permits along the estuarine shoreline in 20 coastal counties. Wetland development activity throughout North Carolina is permitted through the United States Army Corps of Engineers (COE) and the North Carolina Division of Water Quality (DWQ; 401-certification program). Various federal and state environmental and resource agencies, including DMF, evaluate projects proposed for permitting and provide comments and recommendations to the DCM, DWQ, and COE on potential habitat and resource impacts. Habitat protection relies on enforcement, the efforts of commenting agencies to evaluate impacts, and the incorporation of recommendations into permitting decisions.

Federal and state laws mandate water quality protection activities through government commissions and agencies. The North Carolina Division of Water Quality (DWQ) is responsible for the regulation and protection of the State's surface waters. The division's responsibilities include monitoring, permitting, planning, modeling, and compliance oversight. North Carolina has also established a water quality classification and standards program for "best usage" classifications. These are High Quality Waters (HQW), Outstanding Resource Waters (ORW), Nutrient Sensitive Waters (NSW), and Water Supply (WS) waters and outline protective management strategies aimed at controlling point and nonpoint source pollution.

Coastal Habitat Protection Plans (CHPPs). The Fisheries Reform Act (FRA) of 1997 mandated the Department of Environment and Natural Resources (DENR) to prepare a Coastal Habitat Protection Plan (CHPP -- G. S. 143B-279.8). The legislative goal for the CHPP is long-term enhancement of the coastal fisheries associated with coastal habitats and provides a framework for management actions to protect and restore habitats critical to North Carolina's coastal fishery resources. The Coastal Resources Commission (CRC), Environmental Management Commission (EMC), and the MFC must each approve the plans for them to become effective. These three commissions have regulatory jurisdiction over the coastal resources, water, and marine fishery resources. Once plans are approved, actions taken by all three commissions pertaining to the coastal area, including rule making, are to comply, "to the maximum extent practicable" with the plans. Once adopted, the CHPP will help to ensure consistent actions among these three commissions as well as their supporting DENR agencies.

The CHPP describes and documents the use of habitats by species supporting coastal fisheries, status of these habitats, and the impacts of human activities and natural events on those habitats. As an organizational framework the CHPP program uses three basic categories to define habitat that supports coastal fisheries: 1) Fish Habitat, 2) Habitats Beneficial to Coastal Fisheries, and 3) Critical Habitat Areas (Strategic Areas).

Fish Habitat (FH) is defined as freshwater, estuarine, and marine areas that support juvenile and adult populations of economically important fish, shellfish, and crustacean species (commercial and recreational), as well as forage species important in the food chain. FH also includes land areas that are adjacent to, and periodically flooded by riverine and coastal waters. Six FH are discussed

and designated based on distinctive physical properties, ecological functions, and habitat requirements for living components of the habitat: wetlands, submerged aquatic vegetation (SAV), soft bottom, shell bottom, ocean hard bottom, and water column.

A second category of habitat termed “Habitats Beneficial to Coastal Fisheries” (HBCF) is recognized because FH is influenced by overland and subsurface flow from areas that are not physically occupied by coastal fish. Effective management of FH must therefore consider habitat in these areas. Habitats Beneficial to Coastal Fisheries are not adjacent to or periodically flooded by riverine or coastal waters and therefore do not directly support fish populations, but they do provide ecosystem functions that benefit coastal fisheries.

Critical Habitat Areas (CHAs) or “Strategic Areas” is the third basic category and is defined as specific locations of individual fish habitat or systems of habitat that have been identified to provide critical habitat functions or that are particularly at risk due to imminent threats, vulnerability or rarity.

The ‘North Carolina Fisheries Rules for Coastal Waters’ (DMF 2001 – 15A NCAC 3I .0101(20)) defines Critical Habitat Areas as the “fragile estuarine and marine areas that support juvenile and adult populations of economically important seafood species, as well as forage species important in the food chain. Critical habitats include nursery areas, beds of submerged aquatic vegetation, shellfish producing areas, anadromous fish spawning and anadromous fish nursery areas, in all coastal fishing waters as determined through marine and estuarine survey sampling. Critical habitats are vital for portions or the entire life cycle, including the early growth and development of important seafood species.”

The definitions of habitats important to the striped mullet are:

Nursery areas: those areas in which for reasons such as food, cover, bottom type, salinity, temperature and other factors, young finfish and crustaceans spend the major portion of their initial growing season (15A NCAC 3N.0102(a))

Beds of submerged aquatic vegetation: those habitats in public trust and estuarine waters vegetated with one or more species of submerged vegetation such as eelgrass (*Zostera marina*), shoal grass (*Halodule wrightii*) and widgeon grass (*Ruppia maritime*). The presence of aboveground leaves or the belowground rhizomes and propagules together with the sediment on which the plant grows define the bed.

The CHPP focuses on the fish habitat and threats to the habitat. This FMP describes habitat conditions or needs for the various life stages of the striped mullet. The FRA gives precedent to the CHPP and stipulates habitat and water quality considerations in the FMP be consistent with CHPP. Any recommendations will be considered and acted upon through the CHPP implementation process.

9. PRINCIPAL ISSUES AND MANAGEMENT OPTIONS

A summary of the major issues and management options identified during the development of the FMP are contained in this section. Each issue is briefly described along with potential management options, recommended strategies, and actions to be taken by the MFC, DMF, and others. An in-depth discussion of habitat and water quality is in Section 8 (Environmental Factors) while the remaining issues are discussed in Section 11 (Appendices).

9.1 ISSUES

9.1.1 Habitat

9.1.1.1 Issue/ Purpose Protect, enhance, and restore habitats utilized by striped mullet.

Suitable and adequate habitat is a critical element in the ecology and productivity of estuarine systems. Degradation or improvement in one aspect of habitat may have a corresponding impact on water quality. Maintenance and improvement of suitable estuarine habitat and water quality are probably the most important factors in providing sustainable striped mullet stocks.

9.1.1.2 Management Options

1. No regulatory action
2. MFC rule changes to protect additional striped mullet critical habitats
3. Rule changes by other agencies [North Carolina Coastal Resources Commission (CRC), North Carolina Environmental Management Commission (EMC), and others] to protect striped mullet critical habitats and water quality

Option two would require rule changes by the MFC.

9.1.1.3 Recommended Management Strategy

Habitat protection, conservation, and restoration are essential to accomplish the goal and objectives of this plan. The MFC, CRC, and EMC should adopt rules to protect striped mullet critical habitats as outlined in the Coastal Habitat Protection Plans (CHPP). The Department of Environment and Natural Resources (DENR) should develop a strategy to fully support the CHPPs process with additional staff and funding. The MFC and DMF should continue to comment on activities that may impact aquatic habitats and work with permitting agencies to minimize impacts and promote restoration and research. A strategy should be developed and adopted by the MFC and DENR to accomplish the actions outlined in Section 9.1.1.4. These strategies would address objectives 1 and 4 of this plan.

9.1.1.4 Actions

Actions would need to be implemented through the cooperate efforts of several divisions within the DENR. The involvement of federal agencies and increased funding (state and federal) may be necessary to accomplish these actions.

Action 1: Advocate stronger regulatory programs of other agencies as well as work with them to enhance protection of habitat that is critical to striped mullet.

Action 2: Continue to make recommendations on all state and federal, and local permits to minimize impacts to critical habitat areas, especially those pertaining to dredging, beach

nourishment and shoreline stabilization (jetties, groins). The MFC should fully utilize its permit commenting authority as outlined in G.S. 143B-289.52.

Action 3: Identify, research, and designate additional areas as primary nursery areas that may be important to striped mullet as well as other fisheries.

Action 4: Develop and maintain accurate maps and documentation of wetlands, soft bottom, SAVs, and water column.

Action 5: Enhance existing efforts to restore the function and value of degraded wetlands, soft bottom, SAVs, and water column.

Action 6: Continue to investigate the impacts of bottom disturbing gear on habitat.

Action 7: Work with the CRC to modify shoreline stabilization regulations and guidelines to minimize impacts to marine and estuarine resources.

9.1.2 Water Quality

9.1.2.1 Issue/ Purpose Identify, maintain, and enhance water quality critical to the life cycle of the striped mullet.

Suitable water quality is a critical element in the ecology and productivity of estuarine systems. Degradation or improvement in one aspect of water quality may have a corresponding impact on habitat. Maintenance and improvement of suitable estuarine water quality and habitat are probably the most important factors in providing a sustainable striped mullet stock.

9.1.2.2 Management Options

The MFC has no regulatory authority over water quality impacts. The MFC and DMF should highlight problem areas and advise other regulatory agencies (EMC, Division of Water Quality, Division of Environmental Health – Shellfish Sanitation, Division of Land Resources, US Army Corps of Engineers, and local governments) on preferred options and potential solutions.

9.1.2.3 Recommended Management Strategy

The MFC and DMF should continue to comment on activities (state, federal, and local permits) that may impact estuarine water quality and work with permitting agencies to minimize impacts. Additionally, the MFC and DMF should solicit and support funding for projects that may provide information necessary for protection, management, and restoration of water quality. Water quality standards should be based on the assimilative capacity of, and impacts to, the entire system. Several plans for water quality management have recommended strategies that need to be implemented to improve water quality. A strategy should be developed and adopted by the MFC and DENR to accomplish the actions outlined in Section 9.1.2.4, and to assure that existing and future water quality recommendations are addressed in a timely manner. The DENR should develop a strategy to fully support the CHPPs process with additional staff and funding. Water quality protection and restoration are essential to accomplish the goal and objectives of this plan. This strategy would address objectives 1 and 4 of this plan.

9.1.2.4 Actions

Actions would need to be implemented through the cooperate efforts of the N.C. General Assembly and several divisions within the DENR. The involvement of federal agencies and funding (state and federal) will be necessary to accomplish these actions.

Action 1: Advocate stronger regulatory programs of other agencies as well as work with them to

enhance protection of water quality critical to striped mullet.

Action 2: Support research on the causes of hypoxia and anoxia and impacts on striped mullet populations in North Carolina's estuarine waters.

Action 3: Request that EMC adopts measures needed to fully achieve the identified nutrient reduction goals. Initiate nutrient load reduction planning for all watersheds.

Action 4: Support additional research to document and quantify the influences of significant weather events on water quality and assess impacts on the striped mullet population.

Action 5: Recommend and support development and implementation of additional measures to reduce sediment delivery and associated turbidity throughout coastal waters.

Action 6: Recommend and support restoration of non-coastal wetlands and floodplains to offset for losses, in order to improve water quality by restoring natural water filtering and storage processes.

9.1.3 Bycatch Assessment of Striped Mullet in North Carolina Fisheries

9.1.3.1 Issue/ Purpose Striped mullet bycatch within North Carolina commercial inshore fisheries.

The issue of striped mullet bycatch and discard in large ($\geq$ 5 in. stretch) and small (< 5 in. stretch) mesh gill nets, hard crab and peeler pots, ghost pots, crab trawl, and shrimp trawl is examined.

9.1.3.2 Management Options

1. Status quo
2. Implement management measures to reduce bycatch

9.1.3.3 Recommended Management Strategy

The bycatch of striped mullet in commercial fishing gear has been quantified by analyzing fishery-dependent data, fishery-independent data, and DMF Trip Ticket data. Bycatch of striped mullet is not a major concern for North Carolina fishery managers at this time. In the event that size or gear restrictions are established for striped mullet, then the quantity of striped mullet discard (regulatory) may be increased from these estimates. Should this become a concern in the future, these data can be utilized to establish regulations based upon trends, and the numbers and sizes of striped mullet caught by commercial fishing gear type, area, and season. No changes to the rules and regulations are needed based on the relatively insignificant bycatch of striped mullet in North Carolina commercial fisheries. This strategy would address objectives 1 and 2 of this plan.

9.1.3.4 Actions

Action 1: To fully quantify finfish bycatch in North Carolina commercial fisheries, the establishment of a long-term, fishery-dependent observer program is needed.

9.1.4 Characterization of the Bait Mullet Cast Net Fishery

9.1.4.1 Issue/ Purpose Examination and management of the bait mullet cast net fisheries.

There is currently no creel limit for mullet. Consequently, discarding of bait mullets caught in cast nets has been brought to the attention of the DMF. Anglers typically discard dead mullets at the end of a fishing trip, and the number of mullets discarded can be quite large. In addition, law

enforcement and the public have reported anglers taking large amounts of bait mullet from North Carolina and selling them in other states. Because the recreational harvest of mullet is unknown, the waste in the recreational fishery needs to be addressed.

9.1.4.2 Management Options

1. Status quo— no regulations
2. Minimum size limit
3. Trip limit
4. Maximum cast net radius
5. Seasonal closure— prohibit the possession of mullets during the months when only striped mullet are present
6. Area closure—prohibit the commercial harvest of juvenile mullets by cast nets from estuarine habitats where striped mullet is the primary mullet species

9.1.4.3 Recommended Management Strategy

A possession limit of 200 mullets (white and striped in aggregate) per person in the recreational fishery will prohibit anglers from taking large amounts of bait mullet from North Carolina and selling them in other states without impinging on normal fishing practices. A possession limit in the recreational fishery allows Marine Patrol to distinguish between a commercial and a recreational fishing operation. In addition, given the low fishing mortality on striped mullet juveniles estimated from the 2004 stock assessment, there is currently no biological urgency to reduce the recent levels of striped mullet bait harvest.

The amount of waste in the recreational fishery is unknown and poses a concern to many fishermen. The number of juveniles taken for recreational purposes may not significantly impact stock abundance but is perceived as an issue that needs to be addressed. Educating the public on less wasteful practices may help alleviate some of the discards in this fishery. This strategy would address objectives 1, 2, 5, and 6 of this plan.

9.1.4.4 Actions

Action 1: Establish a 200 daily possession limit per person in the recreational fishery.
Action 2: Implement public outreach to reduce waste of mullets in the recreational fishery.
Action 3: Continue estimates of recreational hook and line and bait harvest.
Action 4: Continue sampling the commercial bait mullet cast net fishery to improve the estimate of striped mullet and white mullet harvest.
Action 5: Continue independent cast net sampling to improve the estimate of the proportion of striped mullet and white mullet in the fishery.

9.1.5 Striped Mullet Management Measures

9.1.5.1 Issue/ Purpose Implications of different management approaches needed to continue the sustainability of the striped mullet population.

The North Carolina striped mullet commercial fishery averages 2.18 million pounds per year (1994-2002) and is the largest along the east coast of the United States. Striped mullet are targeted throughout the year with both juvenile and adult fish harvested. However, much of the effort occurs in the fall targeting the adult female (roe) mullet during the spawning migration to the ocean. The recreational fishery is smaller and consists of cast netted juveniles used for hook and line bait and

recreational gill netting of adult fish. An increase in fishing effort after a rise in roe value in the 1980s caused concern for the stock. It was therefore designated as a species of concern in 1999.

9.1.5.2 Management Options

1. Status quo
2. Status quo and establish specific triggers for re-assessment
3. Re-assess stock on a yearly basis
4. Implementation of regulations
   - a). Quotas
   - b). Limited entry
   - c). Size limits
   - d). Closures
     - 1). Season closures
     - 2). Area closures
   - e). Trip/vessel harvest limits
   - f). Gear restrictions
     - 1). Mesh size restrictions
     - 2). Net length restrictions

9.1.5.3 Recommended Management Strategy

Implement no new management measures at this time but establish minimum and maximum landings thresholds of 1.3 million pounds and 3.1 million pounds, respectively. If landings fall below the minimum threshold the DMF would initiate further analysis of the data to determine if the decrease in landings is attributed to stock decline or decreased fishing effort. If landings exceed 3.1 million pounds, the DMF would initiate analysis to determine if harvest is sustainable and assess what factors are driving the increase in harvest. This strategy would address objectives 1, 2, and 5 of this plan.

9.1.5.4 Actions

Action 1: Continue annual age determination and creation of age-length keys.
Action 2: Validate juvenile abundance indices.
Action 3: Annual review of commercial and recreational fisheries.

9.1.6 Pier, Stop Net and Gill Net Fishing Conflicts in the Atlantic Ocean

9.1.6.1 Issue/ Purpose User conflicts in the Atlantic Ocean striped mullet beach seine fishery.

User conflicts in the Atlantic Ocean striped mullet beach seine fishery have existed along Bogue Banks since the mid 1980s and have involved allocation issues between commercial gill netters and the stop net crews, and between the ocean fishing pier owners, pier patrons, and stop net crews. Although not as intense as in years past, these confrontations still occur.

9.1.6.2 Management Options

1. Status quo – permit the fishery to exist under current proclamation authority
2. Adopt current proclamation management measures in rule

9.1.6.3 Recommended Management Strategy

Prior to April 2006, the recommendation was that gill net restrictions on Bogue Banks currently in proclamation should be put into Rule. Next sentence leave as is. With the spring 2006 sale of two of the three ocean fishing piers that are the subject of the current proclamation, it is no longer recommended that the proclamation be put into Rule, but that the proclamation authority be maintained to give the Director the flexibility to deal with whatever arises. It is premature to put the stop net proclamation measures into Rule because of the upcoming NMFS Bottlenose Dolphin Take Reduction Plan (BDTRP) restrictions and the changing nature of the beach seine mullet fishery. Flexibility needs to be maintained for stop net setting sites and gear parameters.

The DMF and AC also recommend to address the new conflict between gill netters and stop netters at the three western Bogue Banks stop nets with a minimum distance requirement. This strategy would address objective 3 of this plan.

9.1.6.4 Actions

Action 1: Maintain status quo by addressing conflict with proclamation authority.
Action 2: Resolve the conflict between gill netters and stop netters.

9.1.7 Inshore Mullet Gill Net Fishing Conflicts

9.1.7.1 Issue/ Purpose Setting of gill nets around private piers and in restricted navigation areas and disruptive practices associated with night fishing.

The change in inshore striped mullet fishing practices from traditional, passive soak nets to active tower boats with runaround nets has created conflicts with marinas and shoreline residents. Setting of gill nets around private piers and in restricted navigation areas and disruptive practices associated with night fishing have resulted in charges against the mullet fishermen of impeding navigation and disturbing the peace. The situation has resulted in petitions for rulemaking asking the MFC for varying degrees of gill net exclusion from specific areas.

9.1.7.2 Management Options

1. Status quo (Continue to handle inshore gill net conflicts on a case-by-case basis and implement management actions to address specific fishery related problems)
2. Adopt 24 hour, 365 day per year gill net closures for high density residential and tourist developments on request
3. Survey water use patterns and designate broad areas as gill net prohibited areas
4. Cease taking any action in proclamation or new rules and use existing rules to manage gill net conflicts

9.1.7.3 Recommended Management Strategy

Inshore gill net conflicts should continue to be handled on a case-by-case basis. This strategy would address objective 3 of this plan.

9.1.7.4 Actions

Action 1: No new action is required.

9.1.8 Management Implications of Proposed NMFS Beach Seine and Stop Net Regulations on Bottlenose Dolphin

9.1.8.1 Issue/ Purpose Recommendations from the Take Reduction Plan for the western Atlantic coastal bottlenose dolphin

The proposed rule that primarily impacts the striped mullet stop net fishery reads, "No person may fish with a net within 300 feet (91.4m) of the beach/water interface unless it consists of multi-fiber nylon (no type of monofilament material) that is 4 inches (10.2 cm) or less stretched mesh". This proposal will prohibit mesh sizes greater than 4 inch for the beach seine and roe mullet stop net fisheries. Under the federal Marine Mammal Protection Act, the NMFS is authorized to implement rules in state waters to protect dolphins and other threatened and endangered mammals.

9.1.8.2 Management Options

1. Status quo – continue to use 6 and 8 inch multifilament webbing
2. Determine what new federal rules will be and react accordingly
3. Encourage fishermen to seek federal funding for conversion of stop nets to legal mesh size
4. Explore possibility of a federal buyout of Bogue Banks stop net fishery

9.1.8.3 Recommended Management Strategy

Fishermen should explore the possibility of a federal funding source for the conversion of the Bogue Banks striped mullet stop nets from the 6 and 8 inch stretch mesh to the pending rule by the NMFS for a maximum of 4 inch stretch mesh. Additionally, fishermen should be allowed to mark their nets in oceanic waters using an identification tag and/or other means of permanent identification such as a permanent marker every 100 yards to identify the state vessel registration number, Coast Guard documentation number, or the state commercial fishing license number. Monofilament gill net less than or equal to five inches should be allowed within 100 yards of beach in North Carolina as long as it is attended. This strategy would address objective 3 of this plan.

9.1.8.4 Actions

No actions are needed. Although no state actions are required, new federal regulations may be implemented as a result of the Bottlenose Dolphin Take Reduction Plan. North Carolina would evaluate those regulations once known

9.2 SUMMARY OF MANAGEMENT ACTIONS

9.2.1 Rules (new, modifications, or technical changes)

See Appendix 9.

9.2.2 Legislative Action

No legislative action is required.

9.2.3 Processes

Sections of State government that will need to be involved in addressing these processes are noted in the parenthesis following each item. Abbreviations for the units of State government are: GA

= NC General Assembly; DENR = Department of Environment and Natural Resources; MFC = Marine Fisheries Commission; and DMF = Division of Marine Fisheries.

1. Advocate stronger regulatory programs of other agencies as well as work with them to enhance protection of habitat that is critical to striped mullet (GA, DENR, MFC, DMF).
2. Continue to make recommendations on all state and federal, and local permits to minimize impacts to critical habitat areas, especially those pertaining to dredging, beach nourishment and shoreline stabilization (jetties, groins). The MFC should fully utilize its permit commenting authority as outlined in G.S. 143B-289.52 (MFC, DMF).
3. Identify, research, and designate additional areas as primary nursery areas that may be important to striped mullet as well as other fisheries (MFC, DMF).
4. Develop and maintain accurate maps and documentation of wetlands, soft bottom, SAVs, and water column (DMF).
5. Enhance existing efforts to restore the function and value of degraded wetlands, soft bottom, SAVs, and water column (GA, DENR, MFC, DMF).
6. Continue to investigate the impacts of bottom disturbing gear on habitat (DMF).
7. Work with the CRC to modify shoreline stabilization regulations and guidelines to minimize impacts to marine and estuarine resources (DENR, MFC, DMF).
8. Advocate stronger regulatory programs of other agencies as well as work with them to enhance protection of water quality critical to striped mullet (GA, DENR, MFC, DMF).
9. Support research on the causes of hypoxia and anoxia and impacts on striped mullet populations in North Carolina's estuarine waters (GA, DENR, MFC, DMF).
10. Request that EMC adopts measures needed to fully achieve the identified nutrient reduction goals. Initiate nutrient load reduction planning for all watersheds (GA, DENR, MFC, DMF).
11. Support additional research to document and quantify the influences of significant weather events on water quality and assess impacts on the striped mullet population (GA, DENR, MFC, DMF).
12. Recommend and support development and implementation of additional measures to reduce sediment delivery and associated turbidity throughout coastal waters (GA, DENR, MFC, DMF).
13. Recommend and support restoration of non-coastal wetlands and floodplains to offset for losses, in order to improve water quality by restoring natural water filtering and storage processes (GA, DENR, MFC, DMF).
14. To fully quantify finfish bycatch in North Carolina commercial fisheries, the establishment of a long-term, fishery-dependent observer program is needed (GA, DENR, MFC, DMF).
15. Implement public outreach to reduce waste of mullets in the recreational fishery (MFC, DMF).
16. Resolve the conflict between gill netters and stop netters (MFC, DMF).
17. Prioritize research needs and implement actions to secure funding and accomplish research (MFC, DMF).

9.2.4 Research Needs (not ranked in order of priority)

9.2.4.1 Biological

1. Improve data on maturity, age-growth, identification of spawning locations, and larval/juvenile movement.
2. To fully quantify finfish bycatch in North Carolina commercial fisheries, the establishment of a long-term, fishery-dependent observer program is needed.
3. Establish a long-term database of adult striped mullet from fishery-independent surveys for the development of an annual abundance index.
4. Improve and validate juvenile abundance estimates.
5. Continue annual age determination and creation of age-length keys.

6. Annual review of commercial and recreational fisheries.
7. Continue improving estimates of recreational hook and line, and bait harvest.
8. Continue sampling the commercial bait mullet cast net fishery to improve the estimates of striped mullet and white mullet harvest.
9. Continue independent cast net sampling to improve estimates of the proportion of striped mullet and white mullet in this fishery.

9.2.4.2 Social and Economic

1. Continue ongoing annual socioeconomic surveys with commercial fishermen, including those who participate in the striped mullet fishery, in order to monitor its social and economic components.
2. Continue ongoing RCGL surveys in order to monitor landings, as well as the social and economic elements of the striped mullet fishery.

9.2.4.3 Education

1. Implement public outreach on waste reduction of mullets in the recreational fishery.

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11. APPENDICES

11.1 Appendix 1 GLOSSARY OF BIOLOGICAL TERMS

Adipose eyelid – vertical folds of adipose (fatty) tissue that protect the cornea of the eye.
Anal fin – (see Figure 1).

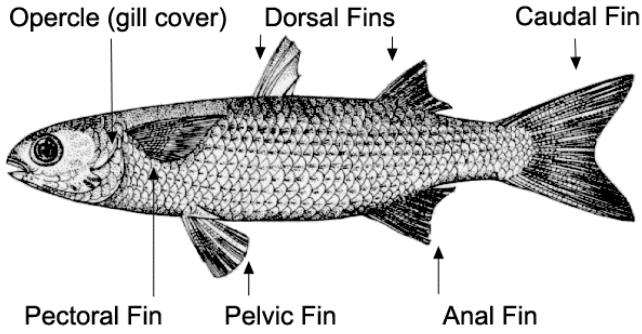

Figure 1. Diagram of fins and opercle.

Annulus – a conspicuous dark band on concentric bony structures (e.g. scales, otoliths) of fishes caused by a period of slow growth similar to growth rings on a tree. Age can be determined by annuli, if fish undergo predictable, yearly, periods of slow growth (e.g. cold winters in temperate climates).
Atrectic – degenerating.
Benthic – occurring on the bottom of a water body (e.g. sea floor, river floor).
Branchial – of, or relating to, the gills.
Carnivorous – feeding on animal tissue.
Catadromous – spending most of the life cycle in freshwater, yet spawning in marine water.
Caudal fin – (see Figure 1).
Detritus – dead plant or animal matter.
Detritivore – organism that feeds on detritus.
Diatomaceous microalgae – unicellular algae with cell walls made of silica.
Diel – occurring each day.
Dorsal fin – (see Figure 1).
Epiphyte – plant (or alga) that grows on the surface of another plant.
Euryhaline – able to tolerate a wide range of salinity changes.
Fecundity – the number of eggs in the ovaries of a female fish, a common measure of reproductive potential in fishes.
Gill lamellae – feather like structures in gill tissue that exchange gases between the gills and the aquatic environment.
Gill rakers – cartilaginous or bony teethlike projections on the gill arches of fishes that aid in capture or retention of prey.
Gonadosomatic Index (GSI) – weight of the gonads expressed as a percentage of the body weight, a common approach to documenting gonad development (Nielsen and Johnson 1992).
Gravid – carrying eggs.
Herbivorous – feeding on plant tissue.
Hermaphroditic – containing both male and female reproductive parts.

In vitro – in an environment outside of the living body; under laboratory conditions.
Isochronal – producing offspring in one batch.
Iteroparous – producing offspring over several periods (e.g. seasons, years).
Marine snow – suspended particles in the water column made of accumulated detritus, mineral grains, phytoplankton, and microorganisms bound in a mucous matrix (Larson and Shanks 1996).
Oil globule – first occurs during development of the egg and persists on the yolk during the yolk sac larval stage; important buoyancy and energy source for developing larva.
Oogenesis – the process of developing ova (eggs).
Opercle – bony plate that covers the gills (see Figure 1).
Osmoregulation – regulation of constant internal water concentration, even if the external environment fluctuates.
Otolith – one of three calcareous (made of calcium) "ear stones" in fishes, which function in equilibrium and detection of sound vibrations.
Pectoral fin – (see Figure 1).
Pelvic fin – (see Figure 1).
Phytoplankton – very small floating or suspended plant life in aquatic ecosystems (e.g. diatoms, microscopic blue-green algae).
Relative fecundity – the number of eggs carried by a fish divided by its body weight.
Spermatogenesis – the process of producing mature sperm cells.
Stenohaline – able to tolerate only a narrow range of salinity changes.
Trophic level – classification of organisms in an ecosystem according to feeding relationships, from first level autotrophs (i.e. plants, algae) through succeeding levels of herbivores, carnivores and decomposers (Smith 1980).
Vitellogenic – during a stage of reproductive development when vitellogenin (a major yolk protein) is incorporated into the oocytes (egg cells).
Yolk sac – pouch containing yolk reserves carried by early stage, free-swimming fish larvae.
Young-of-the-year (YOY) – first year of life for finfishes, also known as age 0.
Zooplankton – floating or weakly swimming animals in aquatic ecosystems (e.g. copepods, early stage fish larvae).

Table 1. Relationships between fecundity and body size.

Author	Area	Fecundity and Body Size Relationship	Correlation Coefficient
Greeley et al. (1987)	Florida	Fecundity = 1,025 * (body weight) + 62,309	(r^2 = 0.81)
Greeley et al. (1987)	Florida	Fecundity = 25.84 * $(SL)^{2.97}$	(r^2 = 0.83)
Render et al. (1995)	Louisiana	Fecundity = 5,683.67 * (FL) - 1,268,864	(r^2 = 0.59)
Bichy (2000)	North Carolina	Fecundity = 1,474.8 * (body weight) - 26,502	(r^2 = 0.92)
Wenner (2001)	South Carolina	Fecundity = 114,998 + 0.016 * $(TL)^3$	(r^2 = 0.90)
Bichy and Taylor (2002)	North Carolina	Fecundity = 12,386 * (FL) - 3,440,451	(r^2 = 0.87)

Table 2. Size at annuli formation (reproduced from Leard et al. 1995).

Author	Area	Aging Method	Fork Length at Formation of Annuli (cm)								
			1	2	3	4	5	6	7	8	9
Jacot (1920)	N. Carolina	scale	12-20	22-23							
Kesteven (1942)	E. Australia	scale	14.9	23.1	31.7	39.7	47.7	53.7			
Thomson (1951)	W. Australia	scale	14.0	24.5	33.6	40.5	46.7	50.5	53.7		
Morovic (1954)	Italy	scale	16.6	24.6	31.8	38.4	42.6	45.1			
Broadhead (1958)	W. Florida	scale	14.2	20.7	26.3						
	W. Florida	scale	13.4	20.7	27.1						
	W. Florida	scale	17.5	25.8	30.7						
	W. Florida	scale	17.8	26.9	31.9	36.6					
Cech & Wohlschlag (1975)	Texas	scale	12.7	18.6	22.5	25.8	28.6				
Pafford (1983)	Georgia	scale	12.3	21.2	25.7	29.4	33.5	36.3	39.8		
Denizci (1958)	Turkey	otolith	4.7	14.5	21.6	30.0	41.8	51.5			
Erman (1959)	Sea of Marmara	otolith		17.1	25.3	33.3	42.6	50.3	55.0	59.0	62.0
Pafford (1983)	Georgia	otolith	14.1	21.2	24.3	27.4	32.0	36.2	39.7	43.4	
Mahmoudi (1990)	Florida	otolith	18.6	24.5	29.3	31.8	33.7	35.6			
	Florida	otolith	18.7	23.9	30.3	34.1	37.2	40.3	42.9	45.2	
Tatum et al. (1993)	Alabama	otolith		21.4	29.5	34.7	38.3	41.0	42.7	43.5	
Thompson et al. (1989)	Louisiana 1986	otolith			37.0	38.1	40.4	41.1			
	Louisiana 1987	otolith			34.2	35.9	38.9	39.3	40.0		

Table 3. Length-weight relationships (reproduced from Leard et al. 1995).

Author	Area		Length-Weight Relationship
Classen et al. (1988)	Texas		$W = 0.000015 * L^{2.93}$
Pafford (1983)	Georgia		
		juvenile	$W = 0.000020 * L^{2.946}$
		female	$W = 0.000065 * L^{2.943}$
		male	$W = 0.000082 * L^{2.694}$
		all	$W = 0.00020 * L^{2.943}$
Thompson et al. (1989)	Louisiana		
		female	$W = 0.000026 * L^{2.85}$
		male	$W = 0.0000096 * L^{3.06}$
Thompson et al. (1991)	Louisiana		$W = 0.000021 * FL^{2.93}$
Mahmoudi (1989)	Florida		
		spawning season	$W = 0.0000052 * FL^{3.17}$
		post-spawning season	$W = 0.000083 * FL^{2.677}$
		summer season	$W = 0.0000066 * FL^{3.14}$
Mahmoudi et al. (1990)	Florida		
		female	$W = 0.00008794 * FL^{3.09}$

11.2 Appendix 2 BYCATCH ASSESSMENT OF STRIPED MULLET (*Mugil cephalus)* IN NORTH CAROLINA FISHERIES

I. ISSUE

Striped mullet (*Mugil cephalus*) bycatch within North Carolina commercial inshore fisheries.

II. BACKGROUND

Fishery managers continually face the issue of bycatch and discards in fisheries throughout the world (Gray 2002). Discards impact fishery yields and fishery managers' ability to accurately assess fishery stocks (Fennessy 1994, Hall 1999). Bycatch is defined as "the portion of a catch taken incidentally to the targeted catch because of non-selectivity of the fishing gear to either species or size differences" [Atlantic States Marine Fisheries Commission (ASMFC) 1994]. Bycatch can be divided into two components: incidental catch and discarded catch. Incidental catch refers to retained or marketable catch of non-targeted species, while discarded catch is that portion of the catch returned to the sea as a result of regulatory, economic, or personal considerations.

The following discussion will explore the issue of striped mullet bycatch and discard in DMF fishery-dependent and fishery-independent surveys. These include commercial fishery-dependent gill net surveys, and independent gill net surveys (IGNS) from large ($\geq$ 5 in. stretch) and small (< 5 in. stretch) mesh gill net fisheries, as well as observer data collections from hard crab and peeler pots, ghost pots, crab trawl, and shrimp trawl.

To accurately assess the bycatch of striped mullet in North Carolina fisheries, data were reviewed from commercial fisheries and fishery-independent surveys, where current observations and analyses have been made by DMF.

It is important to note that the background discussion for large and small mesh gill nets will be limited to seasons (September – December) and area (Pamlico Sound; Outer Banks, and mainland), where current fishery-dependent scientific observations exist. However, in general, the inshore large and small mesh commercial gill net fisheries extend annually throughout the estuarine and riverine waters of North Carolina. Common target species throughout North Carolina in the large mesh fishery include southern flounder (*Paralichthys lethostigma)*, American shad (*Alosa sapidissima)*, hickory shad (*A. mediocris)*, and striped bass (*Morone saxatilis)*. Common target species in the small mesh inshore fishery include spotted seatrout (*Cynoscion nebulosus)*, weakfish (*C. regalis)*, Atlantic croaker (*Micropogonias undulatus)*, spot (*Leiostomus xanthurus)*, white perch (*Morone americana)*, bluefish (*Pomatomus saltatrix)*, and striped mullet (*Mugil cephalus)*.

Large mesh gill net fishery description:

Historically, two large mesh ($\geq$ 5 in stretch mesh) gill net fisheries operated in Pamlico Sound from September – December (Gearhart 2003). These consisted of a shallow water fishery (< 5 ft. deep) along the Outer Banks, and a deep water fishery (10 – 20 ft. deep) further from shore along a slope adjoining the main basin of Pamlico Sound (Figure 1). Both of these fisheries targeted southern flounder. Beginning in 1999

increased observations of sea turtle strandings were made by the National Marine Fisheries Service (NMFS), DMF, and the North Carolina Wildlife Resource Commission (NCWRC). These observations and 2000 monitoring data sparked NMFS to close all potential fishing grounds utilized by the deep water large mesh gill net fishery for the 2001 fishing season (Figure 2, 66 FR 50,350, October 3, 2001).

To maintain this fishery, DMF prepared an application for an Incidental Take Permit (ITP) under Section 10 of the ESA (66 FR 42,845, August 15, 2001), which required an extensive habitat conservation plan (HCP). The NMFS issued ITP #1348 to NCMDF on October 5, 2001 (66 FR 51,023, October 5, 2001), which authorized management measures during the fall of 2001 to protect sea turtles while allowing gill net fisheries to operate within Pamlico Sound (Figure 2). The HCP allows a restricted fishery, and is referred to as the Pamlico Sound Gill Net Restricted Area (PSGNRA). In the PSGNRA, the deep water fishery remains closed, but the shallow water fishery continues to operate under the HCP with many stipulations including: permitted entry, restricted areas, a 2,000 yard limit for all gill net operations, weekly fishermen reporting, and mandatory scientific observer coverage. From the latter, important bycatch data can be obtained.

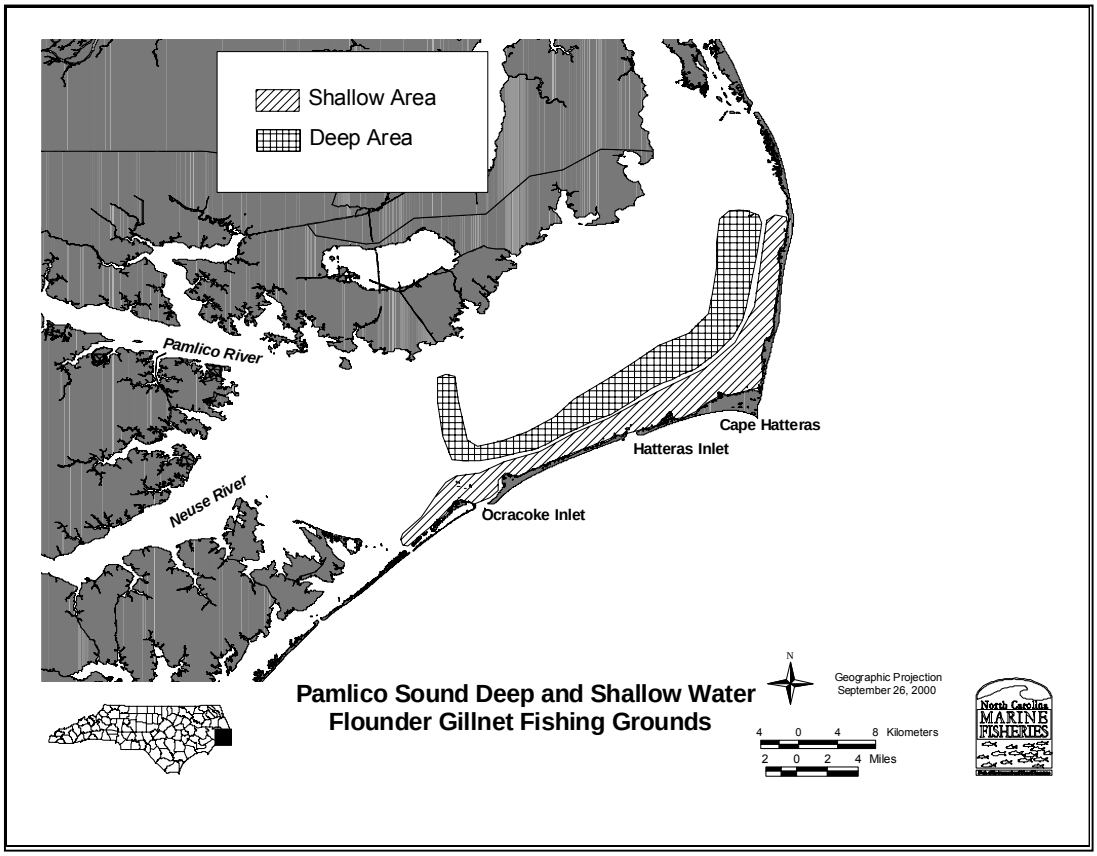

Figure 1. North Carolina estuarine flounder gill net fishing grounds in southeastern Pamlico Sound.

As part of the requirements in the PSGNRA, permit holders were required to

have mandatory observer coverage for the large mesh gill net fishery throughout Pamlico Sound. A list of permit holders was utilized to randomly assign scientific observers to vessels by area (Outer Banks or Mainland) and by port. Outer Banks ports included Rodanthe, Avon, Buxton, Hatteras, Ocracoke, and Cedar Island. Mainland ports (Hyde County) included Stumpy Point, Engelhard, Gull Rock, Swan Quarter, Rose Bay, Germantown, and Hobuken.

Observers collected data on location, gear parameters, catch, and bycatch for each haul. Species status (kept, unmarketable discard, regulatory discard, roe mullet, and white roe) was recorded for each species of each haul. The landed catch was sampled throughout each trip and total flounder weights were obtained. Data were coded on DMF data sheets, double keyed, visually proofed, and uploaded to DMF Biological Database for analysis. All observers were debriefed within 24 hours of each trip to obtain data on flounder catch, set locations, gear parameters, observed bycatch, and sea turtle interactions.

Small mesh gill net fishery description:

Similar to the large mesh gill net fishery, the small mesh gill net fishery operates primarily in shallow water. Within the shallow water small mesh fishery there are two separate fisheries each with different modes of operation; the “runaround” and “set” gill net fisheries. The runaround gill net fishery targets striped mullet and operates year round with most of the effort occurring during the fall from September through November when prices are high due to increased roe content of spawning females. The Pamlico Sound runaround fishery operates in the shallow water areas next to the barrier islands (Figure 1). Fishermen set out in search of schools of striped mullet. Once a school is sighted, one end of the runaround gill net is deployed with a buoy and a small weight (< 3 lb.). The weight creates drag, which enables the rest of the net to be fed out as the fisherman encircles the school of fish. The net is set in a closed circle and fishes the entire water column. Nets are typically 100 - 1000 yd. in length with a stretched mesh of 3 1/2 to 4 1/2 inches. The primary retrieval technique is the open retrieve method where the net is immediately hauled back into the boat starting with the terminal end. A second retrieval technique involves setting only part of the net in a circle and then ‘corkscrewing’ the remainder of the net around inside the circle. This method compresses the fish into smaller areas that forces them to hit the net where they are gilled. Soak times for this fishery are typically less than four hours and nets are attended during the entire operation.

The set gill net fishery (shallow water, small mesh) operates along the Outer Banks, and the mainland side (western) of Pamlico Sound out of ports located in Swan Quarter, Belhaven, and Stumpy Point, North Carolina. Most of the fishing effort occurs from October through early December. Target species include striped mullet, spotted seatrout, weakfish, and bluefish. Nets are anchored overnight similar to the large mesh fishery for flounder that occurs in the same area. Each fishing operation sets 500 to 2,000 yards of small mesh (3 to 4 1/2 inch) gill net, which are retrieved by hand and net reels. In recent years, DMF has enacted rules designating small mesh (< 5 inch stretched) attendance areas along the Outer Banks from March 1 through October 31 to minimize red drum bycatch and subsequent discard mortality (Rule 15A NCAC 3J .0103 (h) in NCMFC 2002). This rule requires small mesh gill net fishermen to remain within 100 yards of their net at all times. From September – December in the PSGNRA, permitted fishermen who operate in the restricted areas, are generally willing to take

scientific observers aboard their vessels. As with the large mesh fishery, these data allow for increased bycatch estimates and further characterization of the small mesh gill net fishery.

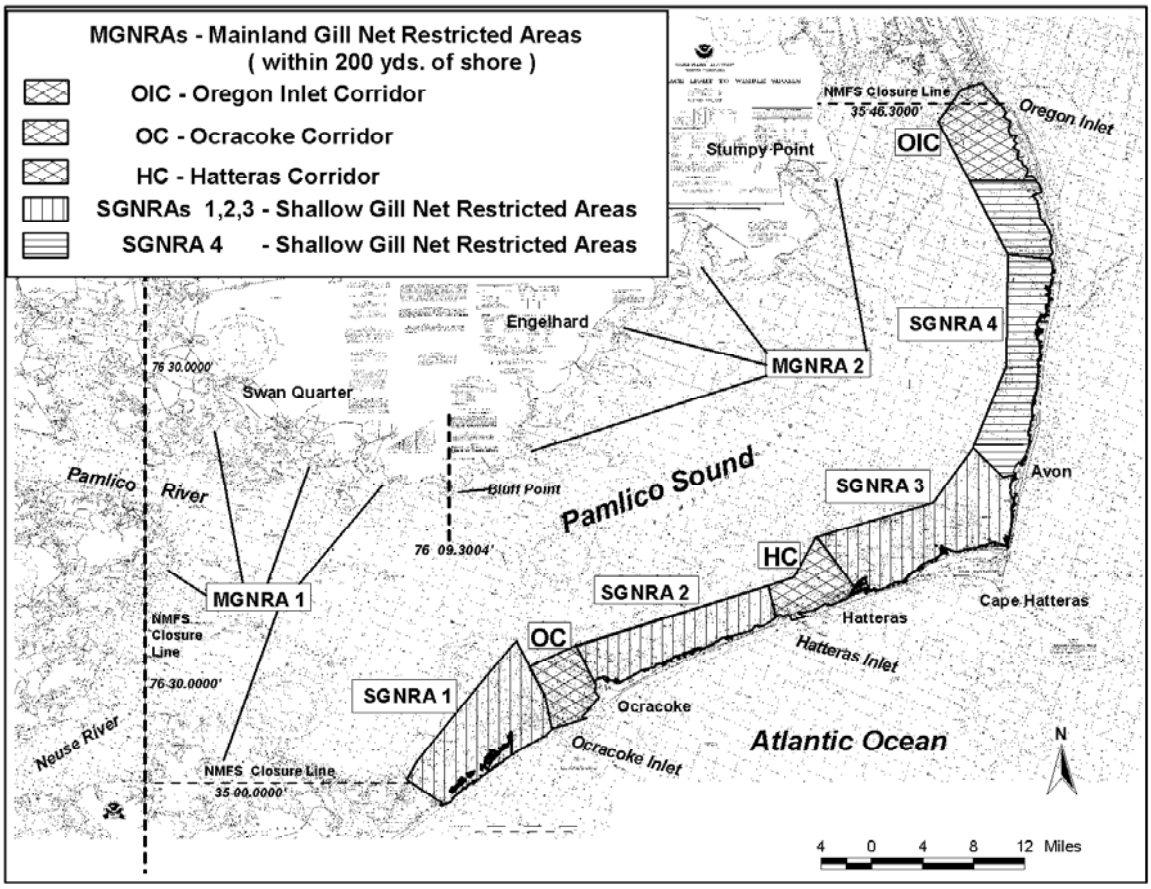

Figure 2. North Carolina estuarine flounder gill net fishing grounds from September – December of the PSGNRA. Map depicts Outer Banks restricted fishing areas (S1, S2, S3, S4), and mainland sites, where fishing is only allowed within 200 yards of shore (M1, M2).

Independent gill net surveys (IGNS) – fishery-independent:

Fishery-independent gill net surveys are used by the DMF to further characterize and address target and incidental captures in North Carolina fisheries. These surveys are used because accurate estimates of numbers and sizes of fish captured in fishery dependent gill net studies (i.e., commercial fishery observations) are often difficult to obtain due to culling of the catch while on the water. Culling at sea would be recorded by observers.

The DMF independent gill net survey is designed to monitor catches in varying mesh sized gill nets (3, 3 ½, 4, 4 ½, 5, 5 ½, 6, 6 ½ in), and estimate species abundance in local areas. These surveys use stratified random grid sampling. Nets are soaked overnight and retrieved the following morning for approximately 12 hr sets. These gill nets are set in shallow (≤ 6 feet) and deep (> 6 feet) waters in areas traditionally utilized by commercial fishermen. The DMF conducts independent gill net surveys throughout

the Pamlico, Pungo, and Neuse River systems, as well as throughout Pamlico and Albemarle Sounds. Analyses of the independent survey data for this study are restricted temporally (September – December) and spatially (Outer Banks and mainland side of Pamlico Sound). This was done in order to compare these data to fishery-dependent observations. In the future, DMF may be able utilize fishery-dependent and fishery-independent comparisons to better manage North Carolina fisheries.

Data collected from independent gill net surveys include: net set and retrieval locations and times; water depth; relevant environmental data noted; biological sampling. Upon retrieval of the nets, fish were enumerated by mesh size, and measured and group weighed. Individual weights were calculated based on length/weight relationships obtained from DMF age sampling. The general condition of the fish (alive, dead, spoiled) captured was recorded.

Hard crab and peeler pots:

The two management issues relating to finfish bycatch in crab pots are: 1) the composition, quantity, and fate of the marketable, and unmarketable discarded bycatch in actively fished pots; and 2) the composition, quantity, and fate of finfish bycatch in "Ghost pots". The DMF Trip Ticket program and various North Carolina Fishery Resource Grant (FRG) studies assess these issues.

Since its inception in 1994, the DMF Trip Ticket program has allowed for more accurate estimates of total fishing effort, target, and incidental catches in the blue crab, *Callinectes sapidus*, pot fishery. In 1999 a Fishery Resource Grant (FRG) was funded to examine bycatch in hard and peeler pots in the Neuse River, North Carolina (Doxey, 99FEG-45).

Ghost pots:

Ghost crab pots are defined as those pots that either through abandonment or loss (float lines cut by boats, storm events, etc.) continue to catch crabs and finfish. Concern stems from the significant increase in the numbers of crab pots, the long life of vinyl coated pots, and the pot's ability to continue to trap crabs and finfish. The number of crab pots used in North Carolina has increased from 350,379 in 1983 to 1,285,748 in 2000. There have been annual reported estimates of 14% crab pot loss for Pamlico and Pungo Rivers (Mckenna and Camp 1992). In a 1999 survey of crab license holders in North Carolina, statewide pot loss in 1998 for hard crab pots was 17% while peeler pot loss was reported at 11%. Total pot use for the same time frame was 853,766 hard crab pots and 163,151 peeler pots (DMF unpublished data, 1998). Estimated crab pot loss for 1998 was 145,140 hard crab pots and 17,947 peeler pots. Reported crab pot loss in N.C. due to Hurricanes Dennis and Floyd was 111,247 (DMF unpublished data from NC Hurricane Floyd Relief Program).

While data exist on the fate and quantity of blue crabs in ghost pots, little information is available on finfish bycatch since dead fish are quickly consumed by blue crabs, leaving only bones and fins (Guillory 1993, DMF unpublished data 1993). Due to this lack of finfish bycatch data from ghost pots, the DMF initiated studies in 2002 to: 1) identify species composition in ghost blue crab pots; 2) determine the length of time that blue crabs and finfish can survive in ghost pots; 3) identify the method and placement of release sites on crab pots to minimize ghost fishing mortality; 4) find a degradable

material that will allow for the escapement of blue crabs and finfish from crab pots after a predetermined length of time; and 5) test escapement panels and biodegradable material under commercial conditions. At present, no bycatch or discard data are available for striped mullet.

Crab trawl fishery:

In North Carolina's internal coastal waters there are very few (less than 25) trawlers that harvest blue crabs exclusively. Since 1994, fishermen that reported crab trawls as at least one of the fishing gears used has ranged from 179 to 418 vessels, and averaged about 290 vessels (DMF Trip Ticket Program). The majority (60%) of the effort in the crab trawl industry, based on number of trips, occurs between March and June.

Crab trawl headrope lengths for double-rigged vessels range from 30 to 45 feet, while twin-rigged vessels usually pull four nets in the 30-foot range. Tow times vary depending on temperature and the amount of biomass encountered. Tow times generally decrease as biomass and/or temperature increases.

The crab trawl fishery has received a large amount of attention due to concern over the bycatch of finfish (mainly southern flounder) and sublegal crabs. To assess this, a study was conducted by DMF in the Pamlico-Pungo river complex to examine this problem (McKenna and Camp 1992).

Shrimp trawl fishery:

Conventional two-seam otter trawls are used for the bottom-hugging pink and brown shrimp, while four seam and tongue trawls with floats on the headrope are used for the white shrimp. In Pamlico Sound, large vessels stay out four or five days and tow from one to three hours, often working day and night. Smaller vessels make daily trips and employ shorter tow times. In the Core Sound area, the fishery occurs mainly at night, with trips lasting one night. In the southern area, fishing is conducted on a day-trip basis, mostly during daylight hours.

III. DISCUSSION

Large and small mesh gill net fishery-dependent observations:

Observed effort

In 2001, there were 122 large mesh gill net trips observed. These consisted of 121,239 yards of gill net observations with a mean soak time of approximately 24 hours (Table 1). There were eighty-two small mesh gill net trips (46,353 yards) with a mean soak time of approximately 24 hours were observed in 2001. In 2002, 155 trips (224,405 yards) of large mesh gill net were observed, each with a mean soak time of 20 hours. Small mesh gill net observations consisted of 41 trips and 22,930 yards with a mean soak time of approximately 11 hours in 2002 (Table 1).

Large mesh results –species compositions

The species compositions of large and small mesh gill net observations in 2001

and 2002 were quantified based upon the fate (kept fish, unmarketable discard, regulatory discard, roe mullet, and white roe) of the fish upon capture. The majority of fish that were retained (kept) included southern flounder, which represented 71% and 67% of the total species composition for 2001 and 2002, respectively. Other predominant species kept in large mesh gill net fishing operations included summer flounder (*Paralichthys dentatus)*, gulf flounder (*P. albigutta)*, bluefish (*Pomatomus saltatrix)*, and black drum (*Pogonius cromis)*. Unmarketable discards consisted of Atlantic menhaden (*Brevortia tyrannus*) (49% and 60% for 2001 and 2002, respectively), rays (Rajiformes*)*, bluefish (spoiled, predation), and pinfish (*Lagodon rhomboides)*. Of the regulatory discards, southern flounder and gulf flounder represented the majority (60%) in 2001, while red drum (*Sciaenops ocellatus)* and southern flounder made up 80% in 2002. Other regulatory discards from large mesh gill nets included summer flounder and gulf flounder in 2001 and 2002. There were very few roe mullet or white roe observed (n = 1 in 2001, and n = 7 in 2002) in large mesh gill net fisheries.

Small mesh results- species compositions

Striped mullet were the primary catches landed from small mesh gill net observations. These represented 46% and 68% of the total catches that were kept from 2001 and 2002, respectively. There were surprisingly high percentages (14% and 15%) of southern flounder kept from 2001 and 2002 small mesh gill net observations. Other marketable species included bluefish, Atlantic menhaden, spot, and black drum. Unmarketable discards from small mesh gill net fisheries consisted of Atlantic menhaden, which represented 65% and 77% of the total unmarketable discards from small mesh gill nets in 2001 and 2002. Other unmarketable discards included rays, sunfish (*Lepomis* spp.), red drum and bluefish. Regulatory discards were principally red drum, which accounted for 42% and 81% of the total in 2001 and 2002. There were significant numbers of regulatory flounder discards (all flounder species combined), which represented 50% and 20% of the total regulatory discards from 2001 and 2002. In both years of small mesh gill net observations, there were numerous roe mullet observed. There were 868 and 1,436 roe mullet caught in each year, respectively. White roe were only observed (n = 216) in small mesh nets in 2001 (Table 1).

Large and small mesh striped mullet discards

Striped mullet bycatch trends were assessed for large and small mesh gill nets in 2001 and 2002 based on number of trips, total yards observed, mean soak hour, and by mullet status (Table 1). Out of the 121,239 yards of large mesh gill net observed in 2001, there were five striped mullets caught and only 1 was discarded. From the 46,353 yards of small mesh gill net observed in 2001, there were 2, 237 striped mullet landed with only 4 individuals (0.18%) discarded. By weight, there were 3.7 kg of striped mullet discarded from small mesh gill net observations in 2001 (Table 1).

From the 224,405 yards of large mesh gill net observations in 2002, there were minimal striped mullet observed (n = 14) in these nets (Table 1). There was only one discard from large mesh gill net observations representing 7% of the total striped mullet catches. There were numerous striped mullet (n = 3,908) observed from the 22,390 yards of small mesh gill net observations in 2002. Of the 3,908 striped mullet landed in small mesh nets, there were two discards representing 0.05% of the total striped mullet caught (Table 1). Combining years and mesh sizes, there were 414,927 yards of gill net

observed. From these there were 6,164 striped mullet caught. Out of 6,164 striped mullet caught (kept, unmarketable discard, roe striped mullet, and white roe), there were 8 discards representing 0.13% of the total striped mullet catches. By weight, out of 6,575 kg of striped mullet caught there was 5.7 kg (0.09%) discarded (Table 1).

Table 1. Striped mullet catches and discards from large and small mesh gill net fishery observations throughout Pamlico Sound, North Carolina from 2001 and 2002.

				Mullet Status									
	Total	Total	Mean	Kept		Unmarketable discard		Regulatory discard		Roe mullet		White roe	
	trips	yards	soak (hr)	n	weight (kg)	n	weight (kg)	n	weight (kg)	n	weight (kg)	n	weight (kg)
2001													
large mesh	122	121,239	23.9	3	8.0	1	0.2	0	0	1	2.0	0	0
small mesh	82	46,353	23.9	1,149	1,106.4	4	3.7	0	0	868	912.2	216	*
2002													
large mesh	155	224,405	20.0	6	9.7	1	0.2	0	0	7	8.5	0	0
small mesh	41	22,930	11.4	2,470	2,511.7	2	1.6	0	0	1,436	2,010.8	0	0
Totals	400	414,927	19.8 **	3,628	3,635.8	8	5.7	0	0	2,312	2,933.5	216	0

* Data not collected
** Mean value

IGNS – fishery-independent:

Striped mullet status and weight - IGNS

Including only September – December data, striped mullet catches from the IGNS were quantified by year, total number of sets, mesh size, location (Outer Banks, Hyde County, and Riverine, which includes the Pamlico, Pungo, Neuse), and by species status upon retrieval (Table 2). In 2001, few striped mullet (n = 7) were caught from a total of 205 independent, large mesh gill net

sets. These were caught in Outer Banks' sites, and no spoiled (unmarketable) striped mullet were observed. From the small mesh surveys in 2001, there were 173 striped mullet caught, or 122 kg in 2001. The majority (83%) of these were caught from Hyde Countysites. No striped mullet were observed in the Riverine sites, and there were no unmarketable individuals (Table 2).

There were 204 independent, large mesh gill net sets made with only 14 observed striped mullet from Outer Banks' sites (Table 2). No spoiled striped mullet were observed. From independent, small mesh surveys in 2002, there was a total of 220 (wt. = 129 kg) striped mullet observed from 226 small mesh sets. These were mostly caught from Hyde County sites (65%). There were only two striped mullet observed from Riverine sites. No spoiled striped mullet were observed (Table 2).

Combining years, mesh sizes, and locations, there was a total of 424 striped mullet caught from 876 large and small mesh independent gill net sets throughout Pamlico Sound, the Neuse River and Pamlico River (Table 2). The majority (n = 382, 90%) of these were alive upon retrieval, and no spoiled (unmarketable) striped mullet were observed. By weight, there was a total of 297 kg of striped mullet caught alive, and 29.1 kg of striped mullet that were dead upon retrieval (Table 2).

Table 2. Striped mullet catches by status from DMF independent gill net survey in large and small mesh gill nets throughout Pamlico Sound and Riverine sites from 2001 and 2002.

		Mullet status								
		Alive			Dead			Spoiled		
	Total sets	n	Total wt (kg)	Mean wt (kg)	n	Total wt (kg)	Mean wt (kg)	n	Total wt (kg)	Mean wt (kg)
2001										
Large mesh										
Outer Banks	98	5	15.3	3.1	2	0.0	0.0	0	0.0	0.0
Hyde Co.*	107	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0
Riverine **	0	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0
Small mesh										
Outer Banks	120	32	22.5	0.7	7	4.3	0.6	0	0.0	0.0
Hyde Co.*	121	130	83.2	0.6	14	11.6	0.8	0	0.0	0.0
Riverine **	0	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0
2002										
Large mesh										
Outer Banks	103	13	22.7	1.7	1	2.0	2.0	0	0.0	0.0
Hyde Co.*	99	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0
Riverine **	2	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0
Small mesh										
Outer Banks	116	72	60.0	0.8	0	0.0	0.0	0	0.0	0.0
Hyde Co.*	106	128	92.2	0.7	18	11.2	0.6	0	0.0	0.0
Riverine **	4	2	1.6	0.8	0	0.0	0.0	0	0.0	0.0
Totals	876	382	297.4	0.8	42	29.1	0.7	0	0.0	0.0

* Mainland side of Pamlico Sound (Figure 2)
** Includes Pamlico, Pungo, and Neuse Rivers

Mullet length frequency - IGNS

Length frequencies were generated from Sept. – Dec. 2001 and 2002 data from the large and small mesh independent gill net surveys. A total of 426 individuals were measured to the nearest inch. Of these 426, only 21 striped mullet were measured from large mesh gill nets. As expected, striped mullet caught in large mesh gill nets were generally larger than those caught in small mesh gill nets (Figure 3). In large mesh gill net samples, striped mullet ranged from 17 – 22 inches in length with the majority (38%) in the 19-in size class. In small mesh samples, striped mullet ranged from 9 – 21 inches in length with the majority of individuals ranging from 12 – 14 inches in length (Figure 3). Most (72%) of the striped mullet caught and measured in small mesh gill nets were obtained from Hyde County (mainland side) sampling sites. There were only two individuals measured from Riverine sites (Figure 3).

Fishery-dependent and fishery-independent comparisons:

In the fishery-dependent and fishery-independent gill net data analyses presented here, the objective was to assess the catches and discards of striped mullet caught in large and small mesh gill nets throughout Pamlico Sound. Similar trends exist in both of these data sets (Table 3).

Fishery-dependent

There were very few striped mullet caught in large mesh gill nets in 2001 and 2002 and nearly 90% of these were kept (Table 3). Combining years and mesh sizes (small and large mesh), the majority (> 99%) of striped mullet encountered in fishery-dependent observations were kept (for market or consumption). By number, there were only eight (0.13%) striped mullet discarded from large and small mesh gill net samples throughout 2001 and 2002. By weight, there were only 10 kg out of 6,659 kg (0.15%) of striped mullet discarded from these samples.

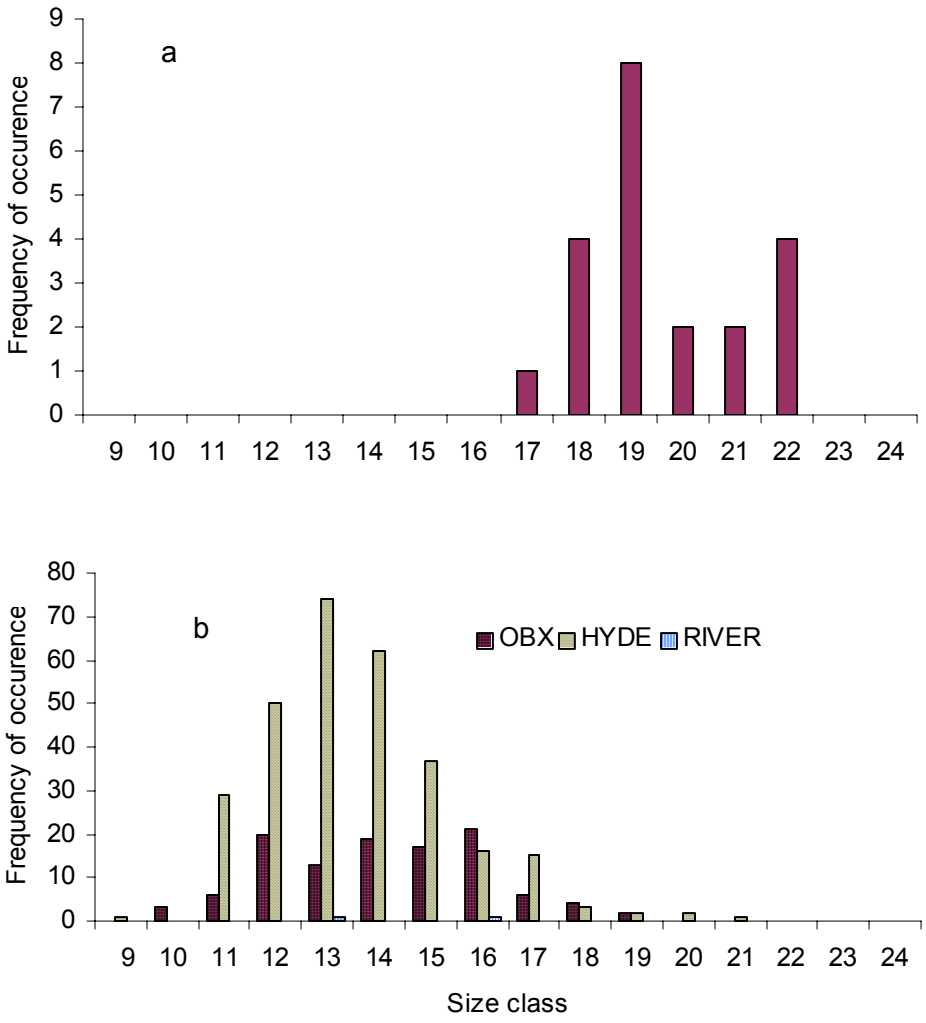

Figure 3. Striped mullet length frequencies by size class (inches) obtained from DMF independent gill net surveys conducted in large (a) and small mesh (b) gill nets throughout Pamlico Sound, the Neuse River, and the Pamlico River. Note: 1) different frequency scale (y-axis), and 2) no measurements obtained from Hyde Co. or River sites in large mesh gill nets.

Fishery-independent

Since there were no spoiled striped mullet, there were no assumed discards in IGNS sampling. These individuals would be considered kept, and thus marketable by the commercial industry. Similar to large mesh gill net fishery-dependent sampling, there were few striped mullet (n = 21, 5%) obtained in large mesh gill nets in the IGNS in 2001 and 2002 (Table 3).

Table 3. Comparison of striped mullet catches and discards from fishery-dependent and fishery-independent sampling conducted from September – December throughout Pamlico Sound, North Carolina in 2001 and 2002.

	Fishery Dependent - Commercial Observing					
	Number		Percent	Weight (kg)		Percent
	Discards	Kept	discards	Discards	Kept	discards
2001						
Large mesh	1	4	20.00	0.2	10.0	1.96
Small mesh	4	2,233	0.18	3.7	2018.6 *	0.18
2002						
Large mesh	1	13	7.14	0.2	18.2	1.09
Small mesh	2	3,906	0.05	5.7	4,522.5	0.13
Totals	8	6,156	0.13	10	6,569.3	0.15

	Fishery Independent - IGNS **					
	Number		Percent	Weight (kg)		Percent
	Discards	Kept	discards	Discards	Kept	discards
2001						
Large mesh	0	7	0.00	0.0	3.1	0.00
Small mesh	0	183	0.00	0.0	122.0	0.00
2002						
Large mesh	0	14	0.00	0.0	25.0	0.00
Small mesh	0	220	0.00	0.0	165.0	0.00
Totals	0	424	0.00	0.0	315.1	0.00

*An additional 216 mullet were not weighed

**Number of discards and weight of discards were based upon condition of fish (alive, dead, or spoiled) upon retrieval, and were assumed to not be discarded unless spoiled.

Hard crab and peeler pots results:

Marketable finfish bycatch

Annual landings of the marketable portion of the incidental finfish bycatch from hard crab pots have averaged 52,185 pounds since 1996 (DMF Trip Ticket Program, 1996-2001, single gear trips). Striped mullet are the sixth most common finfish species landed from this fishery. Annual landings of striped mullet from hard crab pots average 1,004 pounds. Sixty-four percent of the landed striped mullet are captured from

September through November. Striped mullet landings from hard crab pots have been reported from 18 waterbodies. Albemarle Sound accounts for the majority (59%) of the landings, followed by the Pungo River (16%), Roanoke Sound (10%), and the Pamlico River (6%). On average 95,755 hard crab pot trips are reported each year (DMF Trip Ticket Program, 1996-2001, single gear trips). Striped mullet are landed on average from only 44 (0.05 %) of these trips.

Reported average annual finfish landings from peeler pots are 1,002 pounds (DMF Trip Ticket Program, 1996-2001, single gear trips). From 1996 through 2002, peeler pots landed a total of 8 pounds of striped mullet.

Unmarketable bycatch

Four crab pot fishermen kept records of bycatch in their hard and peeler pots from March through October 1999 (Doxey 2000). Hard crab pot data was collected from 283 trips during which 149,649 hard crab pots were fished. Peeler pot data was collected from 11 trips taken in May during which 1,950 peeler pots were fished.

Doxey's 1999 FRG (2000) examined bycatch in hard and peeler pots. From 1,950 trips and 149,649 hard crab pots, 15 striped mullet were captured in hard crab pots, and three in peeler pots. All fish were alive at the time of capture and released in good condition. The average size of mullet in the hard crab pots was 293 mm (11.5 in) and ranged from 147 mm to 406 mm (5.8 in – 16 in). The three striped mullet captured in peeler pots were 152, 179, and 203 mm (6, 7, and 8 in) in length.

Crab trawl results:

Marketable bycatch

Finfish landings by crab trawls average 86,255 pounds per year (DMF Trip Ticket data 1994-2002). The main species landed is southern flounder accounting for 82% of the total finfish landed by crab trawls. Striped mullet landings from crab trawls average 84 pounds per year.

Unmarketable bycatch

McKenna's and Camp's study (1992) assessed the finfish bycatch in the crab trawl fishery. During this study, 15 trips were made aboard commercial crab trawlers. The mean number of tows made during a trip was 3.3, and ranged from 1 to 5. Tow times ranged from 1 to 4 hours and averaged 2.87 hours. An average trip consisted of 9.46 hours of towing. In 50 tows observed one striped mullet was captured.

Shrimp trawl results:

Marketable bycatch

On average 484,468 pounds of finfish are landed by shrimp trawls annually. Striped mullet landings from this gear average 173 pounds per year (1994 – 2002). Since 1996 striped mullet landing by shrimp trawls have averaged 47 pounds. Seventy two percent of the striped mullet landed by shrimp trawls are captured in October and November.

Unmarketable bycatch

In 1999 and 2000, shrimp trawl catches from the Neuse River and Core Sound were examined for bycatch (Johnson 2003). Of the 56 catches sampled 44 striped mullet were captured in three tows.

Other Gears:

Other gears with reported commercial striped mullet landings are; drift gill net, pound nets, long haul seine, swipe net, fyke net, crab pot, gigs, fish pot, rod-n-reel, skimmer trawl, shrimp trawl, crab trawl, trotline, flounder trawl, channel net, eel pot, bull rakes, common seine, turtle pot, clam kicking, and peeler pots (Table 4). Combined, these gears contribute 2% to the total striped mullet harvest. It is very unlikely that there is significant total striped mullet discard from these fisheries.

Table 4. Striped mullet landings (pounds) by gear and year from single gear trip tickets for North Carolina: 1994-2002.

	Year											Percent
Gear	1994	1995	1996	1997	1998	1999	2000	2001	2002	Total	Average	of total
Gill Net (runaround)	564,514	1,186,821	882,866	1,157,809	1,107,811	664,715	1,330,665	1,359,540	1,378,695	9,633,435	1,070,382	49.04
Gill Net Set (sink)	491,842	375,853	351,827	486,089	489,796	444,833	711,122	480,831	719,830	4,552,023	505,780	23.17
Gill Net Set (float)	391,464	553,427	436,656	538,151	410,492	307,845	619,791	342,458	188,261	3,788,546	420,950	19.29
Beach Seine	148,108	78,384	30,450	185,037	148,154	14,904	114,888	89,282	247,242	1,056,448	117,383	5.38
Cast Net	11,397	21,835	18,494	26,413	29,648	15,832	30,238	25,441	38,120	217,419	24,158	1.11
Gill Net (drift)	18,630	45,051	12,072	22,105	22,064	3,508	1,656	4,750	6,239	136,074	15,119	0.69
Pound Net	52,978	12,685	8,413	7,436	6,627	4,882	5,490	3,985	7,393	109,890	12,210	0.56
Long Haul Seine	20,779	16,584	5,926	14,332	956	534	10,390	7,639	2,540	79,681	8,853	0.41
Swipe Net	9,635	89	5,704	2,535	864	1	0	18	176	19,022	2,114	0.1
Fyke Net	6,148	2,676	1,663	370	783	431	1,417	2,192	2,089	17,769	1,974	0.09
Crab Pot	3,788	714	1,072	588	149	2,564	1,470	376	1,195	11,914	1,324	0.06
Gigs	2,039	1,467	1,046	720	635	587	802	472	243	8,012	890	0.04
Fish Pot	2,815	1,529	123	233	4	49	0	76	160	4,990	554	0.03
Rod-n-reel	745	56	0	3	0	0	803	0	1,236	2,842	316	0.01
Skimmer Trawl	25	40	26	0	0	0	0	0	2,460	2,551	283	0.01
Shrimp Trawl	1,007	270	61	91	0	12	43	9	66	1,558	173	0.01
Crab Trawl	31	312	89	70	89	16	104	22	27	760	84	0
Trotline	0	0	0	0	0	0	0	563	0	563	63	0
Flounder Trawl	10	250	0	0	0	0	0	0	0	260	29	0
Channel Net	0	199	0	0	0	0	0	0	0	199	22	0
Eel Pot	0	0	0	0	0	0	195	0	0	195	22	0
Trolling	81	0	0	0	0	0	0	0	0	81	9	0
Rakes, Bull	80	0	0	0	0	0	0	0	0	80	9	0
Turtle Hooks	72	0	0	0	0	0	0	0	0	72	8	0
Common Seine	35	0	0	30	0	0	0	0	0	65	7	0
Turtle Pot	18	0	0	0	0	0	0	0	0	18	2	0
Clam Trawl Kicking	0	0	11	0	0	0	0	0	0	11	1	0
Peeler Pot	0	0	0	0	0	5	0	1	2	8	1	0

Total	1,726,240	2,298,240	1,756,500	2,442,011	2,218,073	1,460,718	2,829,075	2,317,655	2,595,974	19,644,486	2,182,721	100

Conclusion

Gill net fisheries:

It is important to note some assumptions of the fishery-independent gill net sampling. The assumption was made that only spoiled striped mullet would be discarded (i.e., by the commercial industry). This assumption was based upon anticipated marketability and decreased mortality of striped mullet caught in gill nets from September through December 2001 and 2002. The marketability was assumed to be high because waters are generally cooler, have increased dissolved oxygen content, and mean soak times were $\leq$ 12 hr in the IGNS from September - December. Considering these factors, comparisons were made using the commercially dependent gill net observations.

From these two years of commercially dependent and independent gill net sampling in traditional fishing grounds along the Outer Banks and mainland side of Pamlico Sound, the following conclusions are apparent regarding the catch and bycatch of striped mullet in gill nets. Few striped mullet (n = 38 out of 6,580 captures or 0.58%) are captured in large mesh ($\geq$ 5 in stretch) gill nets compared to small mesh (< 5 in stretch) gill nets. Additionally, the majority of striped mullet captured in large mesh gill nets are typically marketable and kept as such. Consequently, by number and by weight, striped mullet discards represent less than 0.15% of the total catch of mullets in large mesh gill nets, and less than or equal to 0.18% of the total striped mullet catches in small mesh gill nets. Finally, striped mullet captured in large mesh gill nets are larger and there are more striped mullet captured in the Hyde County mainland sites of Pamlico Sound than in the Outer Banks. However, this later point may be a reflection of temporal and spatial variability of striped mullet populations, and/or only two years worth of data.

Crab pot fisheries:

Similar to gill net fisheries, crab pots do not appear to be a source of significant bycatch for striped mullet. Through the DMF's Trip Ticket Program, and various studies assessing the bycatch in hard crab and peeler pot fisheries, very few striped mullet were observed. Specifically, striped mullet represented only 0.05% of the finfish bycatch in hard crab pots, and only 8 lbs of striped mullet were observed out of 1,002 lbs of finfish bycatch from peeler pots. Overall, striped mullet bycatch does not appear to be a significant problem in the crab pot fisheries.

Crab and shrimp trawl fisheries:

DMF's trip ticket data and studies assessing striped mullet bycatch (marketable and unmarketable) in trawl fisheries depicted minimal and insignificant catches of striped mullet (i.e., 84 lbs striped mullet out of > 86,000 lbs total finfish bycatch). Considering these results, the bycatch of striped mullet, both marketable and unmarketable, does not appear to be a significant problem in the inshore trawl fisheries.

IV. CURRENT AUTHORITY

SUBCHAPTER 3J - NETS, POTS, DREDGES, AND OTHER FISHING DEVICES

SECTION .0100 - NET RULES, GENERAL

.0103 GILL NETS, SEINES, IDENTIFICATION, RESTRICTIONS

(a) It is unlawful to use a gill net with a mesh length less than 2½ inches.

(b) The Fisheries Director may, by proclamation, limit or prohibit the use of gill nets or seines in coastal waters, or any portion thereof, or impose any or all of the following restrictions on the use of gill nets or seines:

(1) Specify area.
(2) Specify season.
(3) Specify gill net mesh length.
(4) Specify means/methods.
(5) Specify net number and length.

.0104 TRAWL NETS

(a) It is unlawful to use trawl nets for the taking of finfish in internal waters, except that it shall be permissible to take or possess finfish incidental to crab or shrimp trawling in accordance with the following limitations:

(1) It is unlawful to possess aboard a vessel while using a trawl in internal waters more than 500 pounds of finfish from December 1 through February 28 and 1,000 pounds of finfish from March 1 through November 30.
(2) The Fisheries Director may, by proclamation, close any area to trawling for specific time periods in order to secure compliance of this Paragraph.

(d) The Fisheries Director may, with prior consent of the Marine Fisheries Commission, by proclamation, require bycatch reduction devices or codend modifications in trawl nets to reduce the catch of finfish that do not meet size limits or are unmarketable as individual foodfish by reason of size.

SECTION .0500 – OTHER FINFISH

.0502 MULLET

The Fisheries Director may, by proclamation, impose any or all of the following restrictions on the taking of mullet:

(1) Specify season,
(2) Specify areas,
(3) Specify quantity,
(4) Specify means/methods,
(5) Specify size.

V. MANAGEMENT OPTIONS/IMPACTS

(+ Potential positive impact of actions)
(- Potential negative impact of actions)

1. Status quo
+ No rule changes or Legislative actions
+ No additional restrictions on fishing practices
+ No additional burden to law enforcement

2. Implement management measures to reduce bycatch
+ Reduce unmarketable striped mullet bycatch
- Reduction in marketable striped mullet

VI. RECOMMENDATIONS

DMF Recommendation:

No changes to the rules and regulations in the fisheries discussed above are needed based on the relatively insignificant bycatch of striped mullet in North Carolina commercial fisheries.

Advisory Committee Recommendation:

The AC endorsed the DMF management recommendation and research needs.

VII. RESEARCH NEEDS

1. To fully quantify finfish bycatch in North Carolina commercial fisheries, the establishment of a long-term, fishery-dependent observer program is needed.

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11.3 Appendix 3 CHARACTERIZATION OF THE BAIT MULLET CAST NET FISHERY

I. ISSUE

Examination and management of the bait mullet cast net fisheries.

II. BACKGROUND

Juvenile and occasionally adult mullets are caught by cast nets for bait in the recreational fishery. Anglers will catch mullets for personal use while commercial cast netters catch mullets to supply the local tackle shops. Cast netting for mullets occurs along the entire North Carolina coast in creeks, estuaries, inlets and nearshore ocean. Both commercial and recreational cast netting occurs throughout the year with most of the effort during the summer and fall months. Both striped and white mullet are targeted in these fisheries, but the proportion of both species caught in this fishery is unknown.

There is currently no creel limit for mullet. Consequently, discarding of bait mullets caught in cast nets has been brought to the attention of the DMF. Anglers typically discard dead mullets at the end of a fishing trip, and the number of mullets discarded can be quite large. In addition, law enforcement and the public have reported anglers taking large amounts of bait mullets from North Carolina and selling them in other states. Because the recreational harvest of striped mullets is unknown, the waste in the recreational fishery needs to be addressed.

In the fall of 2002, the DMF initiated studies to characterize the recreational and commercial bait mullet cast net fisheries. The overall objective was to determine the proportion of striped mullet and white mullet in these fisheries. Both fishery-independent sampling using cast nets at fixed stations and fishery-dependent sampling of cast net harvested mullets at tackle shops were conducted to meet this objective.

Fishery-independent cast net sampling

The independent sampling was used to characterize the recreational cast net bait fishery. Sampling took place in Dare and Carteret counties in 2002 and 2003 and also in New Hanover County in 2003. Fixed stations were chosen based on different habitats (i.e. ocean, inlet and estuarine locations). Ocean stations were located on piers and on the ocean side of inlets. Inlet stations were shallow water habitats located in the sounds and rivers within 5 miles (8 km) from the closest inlet. Estuarine stations were shallow water habitats located in the sounds and rivers greater than 5 miles (8 km) from the closest inlet. The stations were sampled monthly from late August to November 2002 and from June to November 2003. No sampling occurred from December through May because very little recreational cast netting for mullets occurs during these months. Ocean stations were only sampled from August through November, since mullets are typically scarce, and are not targeted by cast netters in the ocean in June and July. A typical, 6 ft. radius monofilament cast net (3/8 in. bar mesh and ¾ lb. of lead per radius foot) commonly used by recreational bait harvesters was used in the study. A target number of 100 mullets and a maximum of 50 throws were made at each station. Finfish and crustaceans were identified, enumerated and measured. Water temperature (^{o}C), salinity (ppt), dissolved oxygen (mg/L), bottom substrate, tidal stage (when applicable) and water depth (m) were recorded at each location. Samples were sorted by station location and by month to analyze differences in proportions of striped and white mullet.

Fishery-dependent bait shop sampling

Fishery-dependent sampling of mullets caught by the commercial cast net fishery was conducted on a weekly basis at tackle shops in 2002. Sampling occurred from September through November when tackle shops sell cast net-harvested mullet for bait. A sample of mullet from the catch was enumerated by species, measured and weighed and the total weight of the catch sold to the tackle shop was recorded. Information on fishing location, gear parameters and total weight of mullet sold was also collected for each sample. The samples were compared to commercial cast net landings of bait mullet from September through November 1994-2002 to estimate the contributions of striped mullet and white mullet to this fishery.

Results

Fishery-independent cast net sampling

A total of 72 cast net samples were collected from August 2002 to November 2003. The majority of the samples (n = 37) were from inlet stations, 25 samples were from estuarine stations and 10 samples were from ocean stations. White mullet made up the greatest proportion of the samples from June through October, but in November, striped mullet comprised 74% of the mullets in the samples (Figure 1). Across all months, white mullet comprised 93% of the mullets from the ocean stations and 74% of the mullets from the inlet stations, whereas 67% of the mullets from the estuarine stations were striped mullet (Figure 2).

Striped mullet from the independent cast net samples ranged from 50-390 mm FL with 76% of the fish from 70-140 mm FL (Figure 3). White mullet from the independent cast net samples ranged from 40-190 mm FL with 98% of the fish between 60 and 150 mm FL. Sub-adult and adult striped mullet were occasionally caught in the independent samples, but no sub-adult or adult white mullet were captured.

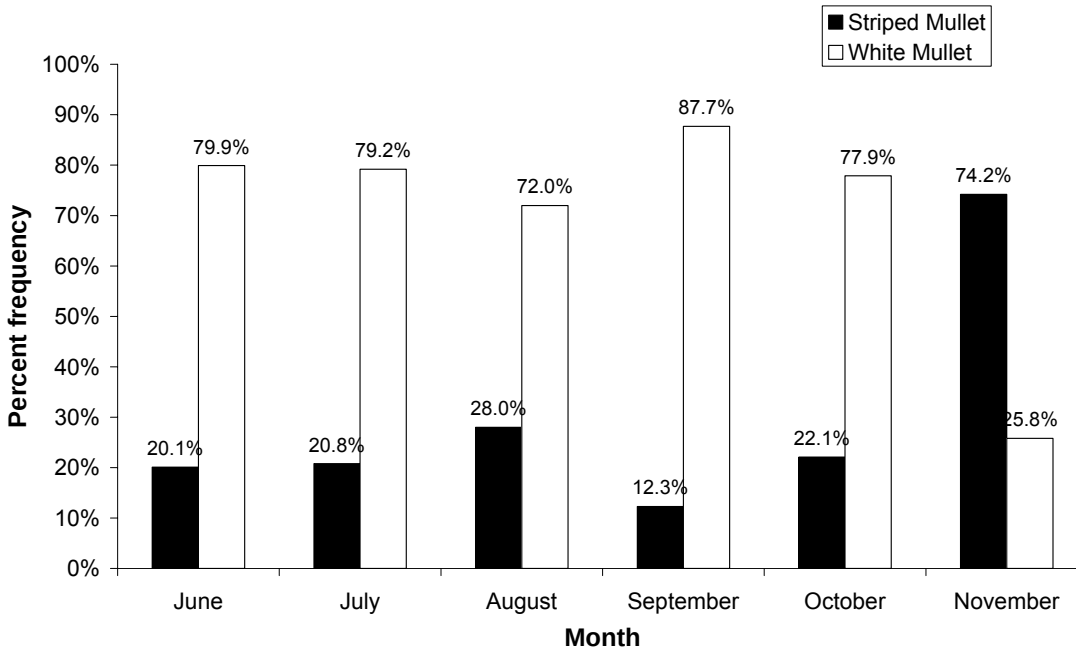

Figure 1. Percent frequencies of striped mullet and white mullet from the independent cast net stations, sorted by month.

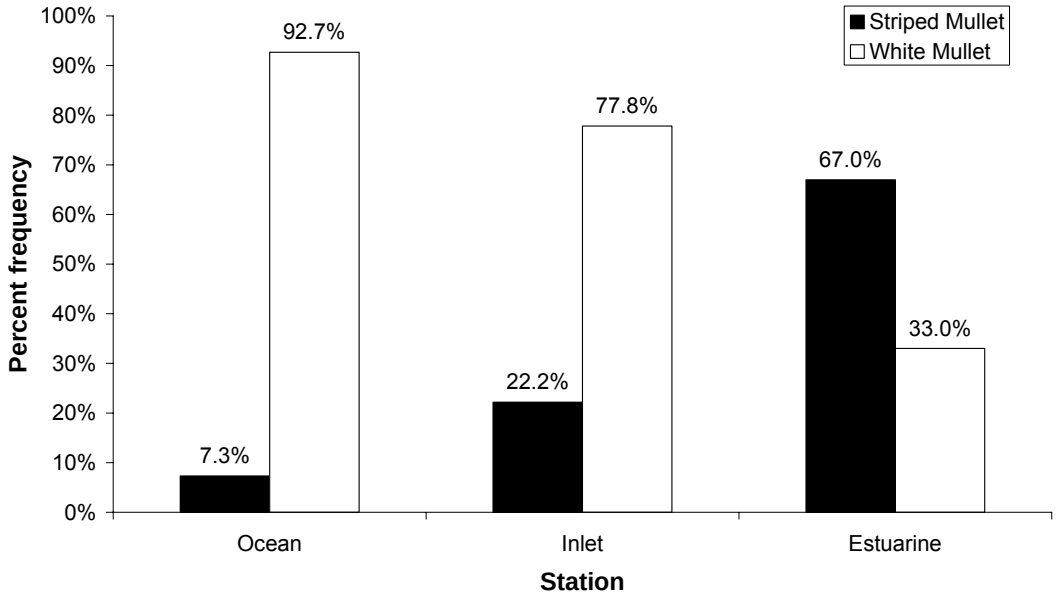

Figure 2. Percent frequencies of striped mullet and white mullet from the independent cast net stations, sorted by location.

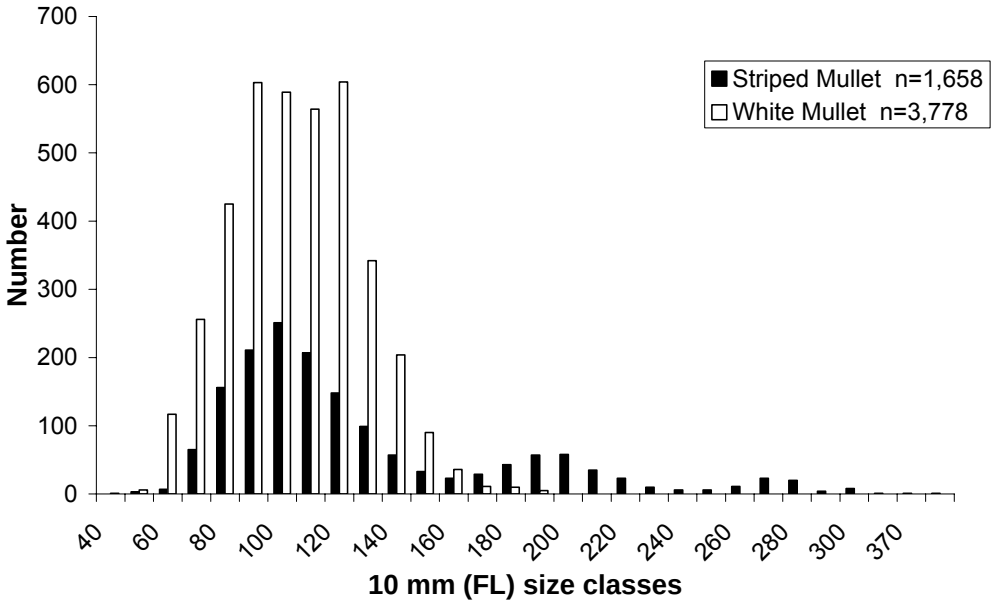

Figure 3. Length frequencies of striped mullet and white mullet from the independent cast net survey, August 2002—November 2003.

Fishery-dependent bait shop sampling

A total of 30 cast net catches were sampled from September through November 2002. White mullet consisted of 95% of the number and 83% of the weight of mullets from the catches sampled in September and 90% of the number and 89% of the catches sampled in October (Table 1). Striped mullet were caught incidentally during these months with only one catch sampled in which striped mullet was the majority of the catch. By November, 100% of the mullets from the catches sampled were striped mullet.

Striped mullet from the commercial cast net catches ranged from 80-290 mm FL with 71% of the fish between 180-220 mm FL (Figure 4). Most of these fish were sampled at bait shops in Dare County and sold as fresh, dead “finger mullet”. Some commercial trips containing live striped mullet were also sampled, exclusively in Carteret County. These live striped mullet ranged between 80-140 mm FL. White mullet from the commercial cast net catches ranged from 80-200 mm FL with the majority between 100-160 mm FL. Only juvenile white mullet and both juvenile and sub-adult striped mullet were present in the commercial catches.

The mean weight of striped mullet sampled was 0.108 kg (0.24 lb) and the mean weight of white mullet sampled was 0.035 kg (0.08 lb). Therefore, the proportion of striped mullet by weight is greater than the proportion of striped mullet by number. Likewise, the length frequency distribution of striped mullet caught in the cast nets was larger than the length frequency distribution of white mullet (Figure 4).

Table 1. Number and weight of striped mullet and white mullet in commercial cast net catches sampled, September—November 2002. Numbers and weights expanded to the collection size of the catches sampled.

	Number		Weight	
	Striped	White	Striped	White
September	693	14,382	105.1	528.3
	4.6%	95.4%	16.6%	83.4%
October	756	8,345	28.0	263.6
	9.9%	90.1%	10.8%	89.2%
November	5,177	0	619.2	0.0
	100.0%	0.0%	100.0%	0.0%

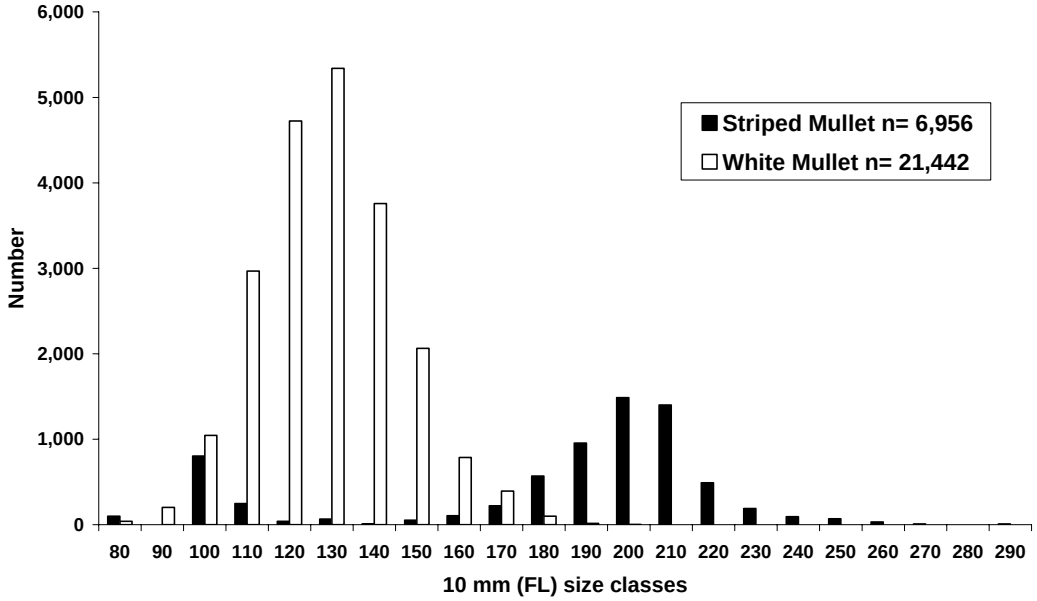

Figure 4. Length frequencies of striped mullet and white mullet from the commercial cast net catches, September—November 2002.

Commercial cast net landings by mullet species

Commercial cast net landings of mullets from September through November 1994-2002 ranged from 8,635 lb in 1994 to 34,641 lb in 2002 and averaged 20,836 lb. (Table 2). Landings were much higher in September and October than in November. When the monthly percentages of striped mullet (by weight) from the commercial cast net catches are applied to the 2002 landings, an estimated 11,451 lb. of striped mullet were landed (33% of 2002 landings) from this fishery. White mullet accounted for 23,190 lb. or 67% of the 2002 landings. The majority of the striped mullet cast net landings came in November when 100% of the bait mullets sampled were striped mullet.

Table 2. Commercial cast net landings of mullets from September—November 1994-2002. Note: roe market landings were removed to only include bait landings.

Year	September	October	November	Total
1994	4,422	4,042	171	8,635
1995	7,432	7,250	3,654	18,336
1996	9,773	6,112	496	16,381
1997	14,619	9,858	223	24,700
1998	8,229	15,280	1,700	25,209
1999	4,048	7,235	549	11,832
2000	9,173	14,466	1,811	25,450
2001	10,721	10,538	1,083	22,342
2002	12,497	14,314	7,830	34,641
Average	8,990.4	9,899.4	1,946.3	20,836.2

III. DISCUSSION

The proportion of striped mullet and white mullet show similar monthly trends between the fishery-dependent and fishery-independent samples. Overall, mostly white mullet are caught from June through October while striped mullet make up the majority of mullets caught in November. White mullet migrate south to Florida in October and November where they spend their adult stage (Mahmoudi 2002). Peak spawning for white mullet occurs from April through June in the offshore waters of the South Atlantic Bight (Collins and Stender 1989). White mullet larvae enter North Carolina's estuaries in the spring and the juveniles become large enough to be caught by cast nets by June. Juvenile and sub-adult striped mullet overwinter in the estuaries of North Carolina (Collins 1985). Therefore, the life history characteristics of these two species are important factors for the monthly proportions observed.

The ocean, inlet and estuarine independent cast net stations showed differences in the proportion of striped mullet and white mullet. Striped mullet were caught primarily in the estuarine stations and secondarily in the inlet stations (Figure 2). White mullet were found in all three categories of stations, but the greatest proportions were caught in the ocean and inlet stations (Figure 2). Most of the commercial cast net catches sampled were from the inlets and the surf zone of the ocean during the fall migration of finger mullet. The proportions of striped mullet and white mullet from the commercial cast net catches and from the independent ocean and inlet stations were similar.

The length frequencies of white mullet were similar between the dependent and independent samples, but the striped mullet length frequencies showed some differences. Since only juvenile white mullet are present in North Carolina, the commercial and recreational cast netters are catching the same size class of fish. A broader size range of striped mullet was found in the independent samples than the commercial samples (Figures 3 and 4). However, the majority of the striped mullet caught in the independent samples were between 70-140 mm FL, while the majority of the striped mullet sampled from the commercial catches were between 180-220 mm FL. Most of the striped mullet caught by the commercial cast netters were in November while striped mullet were caught in the inlet and estuarine independent stations from June through November, thereby capturing a wider size range of fish than the commercial cast netters.

The fall commercial cast net landings of bait mullets are very small compared to the total annual landings of striped mullet in North Carolina. Commercial cast net landings of striped and white mullets from September through November 1994-2002 averaged 20,836 lb compared to total annual landings averaging 2,183,403 lb. from 1994-2002. The dependent sampling of the commercial cast net fishery showed that this fishery lands both striped mullet and white mullet. However, white mullet are rarely harvested in other commercial gears. An estimated 11,451 lb. of striped mullet was harvested in 2002 by the commercial cast net fishery when the monthly percentages of striped mullet (by weight) from the commercial cast net catches were applied to the 2002 landings. November 2002 landings of mullets were much higher than November landings in previous years. The commercial cast net samples in 2002 showed 100% of the mullet sampled in November were striped mullet, but a small proportion of white mullet were found in the November independent samples. Only one season of commercial cast net fishery data was collected, so some differences in the monthly proportions of striped mullet and white mullet are possible with multiple seasons of data. It is therefore inappropriate to apply the monthly percentages of striped mullet from the 2002 commercial cast net catches to landings from previous years. However, the small overall landings from cast nets and the significant proportion of white mullet harvested by commercial cast nets indicate that striped mullet from the commercial cast net fishery contribute a very minor portion to the entire commercial striped mullet fishery.

Reliable estimates of the recreational harvest of striped mullet and white mullet are not available. Without harvest estimates, discard estimates for this fishery are impossible to obtain. Reports of discarding received by the DMF have coincided with the fall ocean migration of finger mullets in September and October. The independent and dependent sampling showed that most of these mullets are white mullet. It is likely that discarding occurs throughout the year when the recreational fishery occurs, and it is likely that the majority of mullets discarded are white mullet. Although this fishery management plan only pertains to striped mullet, the discarding of white mullet is a concern.

The Marine Recreational Fisheries Statistics Survey (MRFSS) in North Carolina has harvest estimates for striped mullet but not for white mullet. White mullet are most likely misidentified as striped mullet and mullets released by anglers are not observed by MRFSS creel clerks and therefore cannot be identified to species level. The ratios of striped mullet and white mullet from the fishery-independent sampling can be applied to the MRFSS landings for better harvest estimates of these mullet species in the recreational fishery.

There is little justification for enacting regulations for reducing the cast net bait harvest of striped mullet at this time. The overharvest of juveniles has not been substantiated because MRFSS estimates of the recreational bait harvest of mullets are only beginning to be produced and refined. As such, the percentage of striped mullet in the existing MRFSS harvest estimates would be quite reduced based on the results of this study. However, the anecdotal accounts of discarded bait mullets from anglers are an issue that can be addressed by management options.

IV. CURRENT AUTHORITY

SECTION .0100 – FINFISH, GENERAL

.0103 MINIMUM SIZE LIMITS

It shall be unlawful to possess, sell, or purchase fish under four inches in length except:

(1) for use as bait in the crab pot fishery in North Carolina with the following provision: such crab pot bait shall not be transported west of U.S. Interstate 95 and when transported, shall be accompanied by documentation showing the name and address of the shipper, the name and address of the consignee, and the total weight of the shipment.

(2) for use as bait in the finfish fishery with the following provisions:

(a) It shall be unlawful to possess more than 200 pounds of live fish or 100 pounds of dead fish.

(b) Such finfish bait may not be transported outside the State of North Carolina.

Bait dealers who possess valid finfish dealers license from the Division of Marine Fisheries are exempt from Subitems (2)(a) and (b) of this Rule. Tolerance of not more than five percent shall be allowed. Menhaden, herring, gizzard shad, pinfish and live fish in aquaria other than those for which a minimum size exists are exempt from this Rule.

History Note: Authority G.S. 113-134; 113-185; 143B-289.52;
Eff. July 1, 1993.

15A NCAC 3M .0502 MULLET

The Fisheries Director may, by proclamation, impose any or all of the following restrictions on the taking of mullet:

(1) Specify season,
(2) Specify areas,
(3) Specify quantity,
(4) Specify means/methods,
(5) Specify size.

V. MANAGEMENT OPTIONS/IMPACTS

(+ Potential positive impact of actions)
(- Potential negative impact of actions)

Recreational Cast Net Fishery

1. Status quo—no regulations
   + No new regulations on anglers
   + No new enforcement responsibilities
   - Continued mortality of discarded bait mullets
   - Potential overharvest of juvenile striped mullet

2. Minimum size limit
   + Reduced harvest and fishing mortality of juvenile mullets
   - Increased enforcement responsibilities
   - Prohibited possession of mullets commonly used as bait
   - Regulatory discards of undersized mullets

3. Possession limit
   + Reduced discarding of mullets by anglers
   + Reduced harvest and fishing mortality of juvenile mullets
   + Allows Marine Patrol to distinguish between a commercial and a recreational fishing operation
   - Increased enforcement responsibilities
   - Potential problems enforcing possession limit (multiple anglers, counting live mullets in bait wells, anglers purchasing mullets from bait shops).

4. Maximum cast net radius
   + Potential reduction in harvest and fishing mortality of juvenile mullets
   + Reduced discards of mullets
   - Increased enforcement responsibilities

5. Seasonal closure—prohibit the possession of mullets during the months when only striped mullet are present.
   + Limits the harvest of striped mullet without significantly affecting white mullet harvest
   + Reduction of fishing mortality of juvenile striped mullet
   + Closure when recreational harvest of mullets is minimal
   - Increased enforcement responsibilities
   - Reduction in harvest potentially minimal compared to impact of regulations on anglers

6. Area closure—prohibit the recreational harvest of juvenile mullets by cast nets from estuarine habitats where striped mullet is the primary mullet species.
   + Limits the harvest of striped mullet without significantly affecting white mullet harvest
   - Anglers fishing in the western sections of the estuaries will no longer be allowed to cast net for mullets
   - Increased enforcement responsibilities

Commercial Cast Net Fishery

1. Status quo—no regulations
   + No new regulations on commercial cast netters
   + No new enforcement responsibilities
   - Potential overharvest of juvenile striped mullet

2. Minimum size limit
   + Reduced harvest and fishing mortality of juvenile mullets
   - Increased enforcement responsibilities
   - Prohibited possession of mullets commonly used as bait
   - Loss of income from small mullets that can no longer be harvested
   - Regulatory discards of undersized mullets

3. Trip limit
   + Reduced harvest and fishing mortality of juvenile mullets
   - Increased enforcement responsibilities
   - Increased regulatory discards of mullets that exceed the trip limit
   - Loss of income from reduced harvest

4. Maximum cast net radius
   + Potential reduction in harvest and fishing mortality of juvenile mullets
   - Prohibition of cast nets commonly used in this fishery
   - Increased enforcement responsibilities
   - Increased effort required to equal harvest from larger cast nets

5. Seasonal closure—prohibit the possession of mullets during the months when only striped mullet are present.
   + Limits the harvest of striped mullet without significantly affecting white mullet harvest
   + Reduction of fishing mortality of juvenile striped mullet
   + Closure when commercial harvest of mullets by cast nets is lower
   - Increased enforcement responsibilities
   - Reduction in harvest potentially minimal compared to impact of regulations on commercial cast netters
   - Loss of income from not landing mullets during the closed season
   - Juvenile mullets unavailable to tackle shops during part of the year

6. Area closure—prohibit the commercial harvest of juvenile mullets by cast nets from estuarine habitats where striped mullet is the primary mullet species.
   + Limits the harvest of striped mullet without significantly affecting white mullet harvest
   + Reduction in fishing mortality of juvenile striped mullet
   - Increased enforcement responsibilities
   - Loss of income for cast netters harvesting mullets in closed areas

VI. RECOMMENDATIONS

DMF Recommendation:

Implement a possession limit of 200 mullets (white and striped in aggregate) per person in the recreational fishery. The intent is to eliminate anglers from taking large amounts of bait mullets from North Carolina and selling them in other states without impinging on normal fishing practices. A possession limit in the recreational fishery allows Marine Patrol to distinguish between a commercial and a recreational fishing operation. And given the low fishing mortality on striped mullet juveniles estimated from the 2004 stock assessment, there is currently no biological urgency to reduce the recent levels of striped mullet bait harvest.

Implement public outreach on waste reduction of mullets in the recreational fishery. Waste in the recreational fishery is unknown and poses a concern to many fishermen. The number of juveniles taken for recreational purposes may not greatly impact stock abundance but is perceived as an issue that needs to be addressed. Educating the public on less wasteful practices may help alleviate some of the discards in this fishery.

Advisory Committee Recommendation:

The AC endorsed DMF recommendations for a 200 recreational limit, and public outreach.

VII. RESEARCH NEEDS

1. Continue improving the estimates from the recreational hook and line and bait harvest.
2. Continue sampling the commercial bait mullet cast net fishery to improve the estimate of striped mullet and white mullet harvest.
3. Continue independent cast net sampling to improve the estimate of the proportion of striped mullet and white mullet in this fishery.

VIII. LITERATURE CITED

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11.4 Appendix 4 STRIPED MULLET MANAGEMENT MEASURES

I. ISSUE

Implications of different management approaches needed to continue the sustainability of the striped mullet population.

II. BACKGROUND

The North Carolina striped mullet commercial fishery averages 2.18 million pounds per year (1994-2002) and is the largest along the east coast of the United States. Striped mullet are targeted throughout the year with both juvenile and adult fish harvested. However, much of the effort occurs in the fall targeting the adult female (roe) striped mullet during the spawning migration to the ocean. The recreational fishery is smaller and consists of cast netted juveniles used for hook and line bait and recreational gill netting of adult fish. An increase in fishing effort after a rise in roe value in the 1980s caused concern for the stock. It was therefore designated as a species of concern in 1999.

A population assessment of the North Carolina striped mullet was conducted using a forward projection analysis incorporating several fishery-dependent and independent data sets. Spawning stock biomass (SSB) has increased and the three highest estimates of age 0 recruitment occurred in the last five years, peaking in 2002. Although the female stock is heavily exploited, overfishing is not occurring. Females are able to mature because of low commercial fishing mortality in January-June, combined with the selectivity of older fish in July-December. Fishing mortality from recreational fishing is low with mortality occurring on age 0 fish in the summer and fall.

Although overfishing is not occurring, it is currently being fished near the maximum exploitation level that can maintain sustainability. This leaves little room for any uncertainty in data used in the assessment or against unpredictable events that may occur in the future (Figure 1). An *F*-based commercial threshold on females based on SPR =25% ($F_{25\%}$ =1.25), should be appropriate to maintain the recent harvest level while ensuring the sustainability of the stock. Female fishing mortality has stabilized in the last five years with the heaviest exploitation occurring early in the time series. Historically, the commercial fishery has sustained landings similar in scope to current levels (with wide fluctuations) for over 100 years (see Commercial Fishery section), with the historical median catch equal to 2,132,301 lb and the 1994-2002 median =2,298,240 lb (average =2,182,721 million lb).

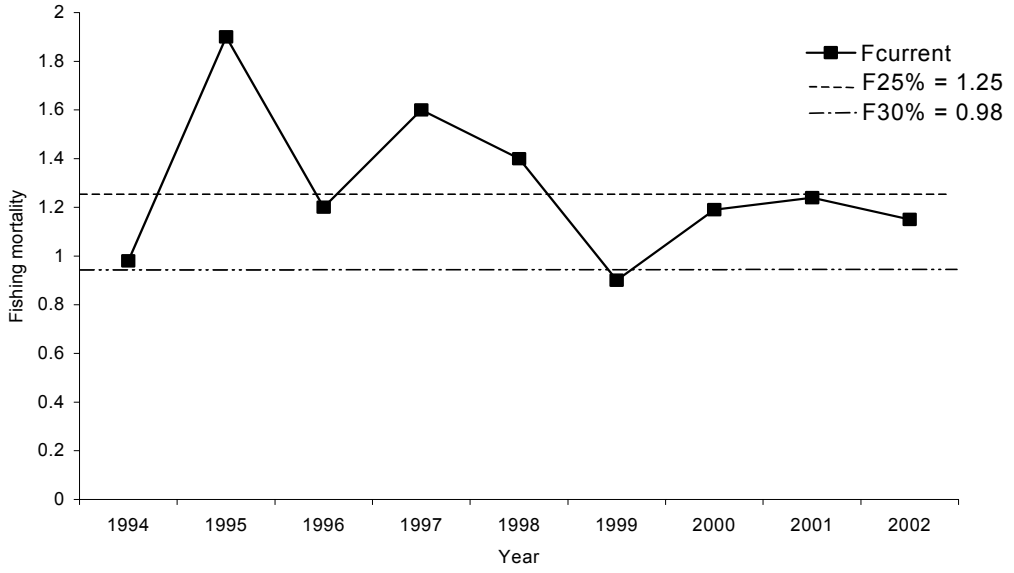

Figure 1. Striped mullet female fishing mortality (1994-2002) in relation to F_{Target} ($F_{30\%}$) and $F_{Threshold}$ ($F_{25\%}$).

III. DISCUSSION

Four management options will be discussed for the striped mullet fishery. One approach is status quo. The Division of Marine Fisheries (DMF) currently reviews landings (commercial and recreational), indices of abundance (juvenile and adult), market conditions, and environmental factors annually for the Marine Fisheries Commission (MFC) stock status report. The stock would be re-assessed in 2010 as required by the Fisheries Reform Act, unless the annual review indicated otherwise, and management measures would be implemented if needed. The other three management approaches are to: 1). Status quo and establish specific triggers for re-assessment; 2) take a more proactive or precautionary approach by re-assessing the stock on a yearly basis; or 3). implement management measures to ensure that fishing mortality remains at or below the target fishing mortality.

Status quo and establish triggers for re-assessment

This option would result in no new management measures to the striped mullet fishery but would establish minimum and maximum commercial landings thresholds two standard deviations above and below the mean commercial landings from 1994-2002. Commercial landings below the minimum threshold (1.3 million pounds) would initiate further analysis of the data to determine if a sharp decrease in landings is attributed to stock decline or decreased fishing effort. Likewise, commercial landings exceeding the maximum landings threshold (3.1 million pounds) would be analyzed to see if it is sustainable and determine if market shifts have occurred that need to be addressed.

Yearly re-assessment of stock status

This option would be an adaptive, data-based management strategy for the stock that would protect against uncertainty or unpredictability in future events. This would be

accomplished by yearly monitoring of the various data sets used in the stock assessment such as the juvenile recruitment indices, adult indices, size and age structure of the fishery as well as landings in relation to fishing effort. Triggers would be established to monitor the databases. If triggers are met and declining trends are observed in the data, a full assessment would be conducted. Based on findings of a new assessment, appropriate management measures would then be put in place.

Implementation of regulations to remain below fishing mortality targets

There are several regulatory measures that can be considered in the management of striped mullet. These are: quotas, limited entry, size regulations, seasonal or area closures, trip/harvest limits, gear restrictions, or a combination of these measures.

Quotas

A quota is the maximum amount of fish that can be legally landed within a specified time period. The intent for implementing a quota on any fishery is to prevent further expansion and reduce or stabilize harvest. There have been a lot of fluctuations in annual landings of striped mullet in recent years and it would be difficult to establish a reasonable harvest cap. The North Carolina striped mullet fishery changed markedly in the late 1980s with increased demand from Asia for striped mullet roe. From 1972 to 1986, annual landings in the mullet fishery averaged 1.66 million lb, with a range of 1.07 to 2.22 million lb (Figure 2). Average annual landings from 1987 to 1993 were 2.44 million lb, with landings near or exceeding 3 million lb in 1988, 1990, and 1993. In 1988, landings exceeded 3 million lb for the first time in 28 years.

Due to variability in recruitment, a quota may not prevent overfishing during years where there is poor recruitment. A quota has to be monitored with dealer reporting, which would be an additional burden to the commercial fish house dealers and the DMF. There are over 2,000 participants involved in the fishery and about 200 dealers (see Socioeconomic section).

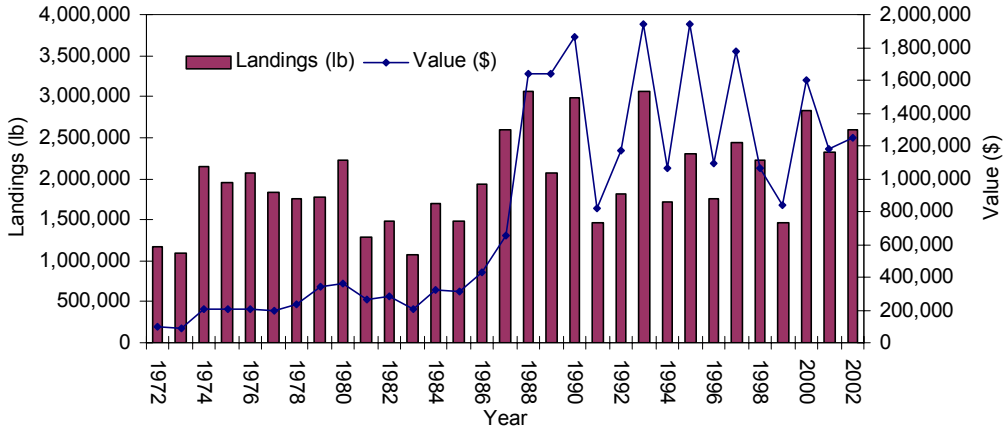

Figure 2 Yearly landings and value from 1972-2002. Values ($) were not adjusted for inflation. In 1988, landings exceeded 3 million lb for the first time since 1960 and value increased by 150%.

Limited Entry

A limited entry system would prevent expansion in the commercial fishery beyond a specified level of participants. Overfishing could still occur because it would not prevent an increase in effort by those individuals allowed in the fishery. Section 2.1 of the Fisheries Reform Act (G.S. 113-182.1) concerning Fishery Management Plans (FMP's) states that the North Carolina Marine Fisheries Commission (MFC) can only recommend that the General Assembly limit participation in a fishery if the MFC determines that sustainable harvest in the fishery cannot otherwise be achieved. Sustainable harvest can be maintained with status quo therefore limited entry cannot be considered an option.

Size Limits

Size regulations are a management tool based on the species' reproduction and life history. Minimum size limits allow fish to spawn at least once contributing to the growth of that fishes' population before capture. Maximum size limits are used to protect the larger fish that produce more eggs. Harvest slot limits are a size range in which fish may be kept. This protects both the smaller immature fish and the large females that may produce more eggs than smaller females. Protected slot limits consist of a size range in which fish must be released. The purpose of this type of limit is to protect medium sized fish so that they may grow larger and to protect a size class that may be very prolific. While size limits are effective management tools in other fisheries, it may not be effective in the striped mullet commercial fishery. Juvenile and adult striped mullet cover a broad size range (60-640 mm) in the commercial harvest, which includes trips targeting striped mullet as well as trips targeting other species (Figure 3). Because almost all commercially caught striped mullet are marketable, discards of striped mullet in directed and other fisheries are very low (see Bycatch issue paper). Implementing size limits for striped mullet will increase discards in both directed and other fisheries, and diminish conservation of the spawning stock biomass. Special caution should be taken to not change the commercial fishery selectivity pattern towards the targeting of smaller sized fish. If the fishery selectivity changes towards smaller, younger fish, the threshold *F* will be lowered, defeating the effectiveness of the management action (see Stock status section).

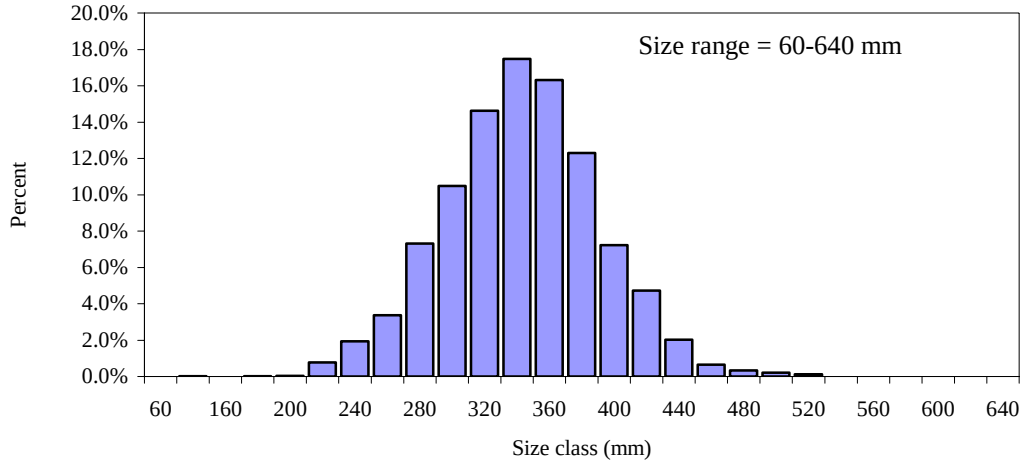

Figure 3. Length distribution (mm) of striped mullet in the North Carolina commercial fishery: 1994-2002.

Seasonal or Area Closures

Seasonal closures are intended to protect a portion of the stock in order to increase spawning stock biomass with the least impact to fishermen. The months of December and January still have some spawning females available and landings have dropped within the fishery when there may be a reduced economic impact to fishermen.

Annual striped mullet SSB was based on mature females at 1 January of the following calendar year (e.g. 1994 SSB was based on the weight of all mature females on 1 January 1995). Most commercial fishing mortality on females occurs on roe (pre-spawned) individuals in July-December of each year. By calculating the average harvest of mature females in the month of December the savings is additive to the average annual SSB. Eliminating harvest from the month of December would allow a savings of 16,818 kgs (1.99% of SSB) of mature females from the population based on the average amount of fish harvested from 1994-2002. However, the savings from the month of January is not additive to the annual SSB because almost all the fishing mortality occurs on pre-spawned females in July-December of each year. A possible result of a seasonal closure is an increase in effort during the open period to compensate for the seasonal closure. Increased landings during the open period could minimize the savings of mature females from the seasonal closure because it could increase the harvest of smaller fish.

Economic impacts on fishermen from a closure will vary by area and gear type. The month of December accounts for 4.3% of the annual striped mullet landings (pounds) and 3.3% by value (Table 1). The month of January accounts for 6.0% of the annual striped mullet landings (pounds) and 4.0% by value. The Rivers (Pamlico, Neuse, Pungo, and New rivers) would be affected the most for both months (37.2% overall Dec-Jan). The Albemarle area would take the greatest impact in January. If it were only a December closure, impacts would be equal between the Rivers and the Albemarle area. Catches would be eliminated for striped mullet in the directed fishery

and in fisheries targeting perches and striped bass in the Albemarle and spotted seatrout in the Rivers. A total of 597 trips targeted (> 50% by weight of trip) striped mullet in both December and January, which accounted for 15.7% of all the gill net trips in inside waters for these months (average 1994-2002). The majority of the trips in these months (n=3,802; 84.3%) with striped mullet in the catch are not directly targeting for striped mullet therefore they would become discards.

Area closures can provide a safe haven for fish to live and reproduce. This type of closure is used to protect waters where fish congregate at or before spawning, and where fish may contribute to nearby areas that are fished. Area closures are also used to protect habitat that is essential to a portion of the life history of a managed species. Because striped mullet use a variety of habitats at different life stages and different times of the year, identifying particular areas to serve as refuge would be difficult (see Environmental Factors section).

Table 1. Average annual commercial landings (lbs.) and value of striped mullet by area for the months of January and December in gill nets, 1994-2002.

	January		December		Entire year	
Area	Pounds	Value	Pounds	Value	Pounds	Value
Albemarle area	53,579	20,480	18,821	8,115	379,816	178,201
	41.2%	38.7%	20.3%	18.6%	17.4%	13.6%
Ocean	957	420	2,911	1,770	261,461	174,569
	0.7%	0.8%	3.1%	4.1%	12.0%	13.3%
Pamlico area	15,414	6,564	14,069	6,857	701,057	457,977
	11.8%	12.4%	15.2%	15.7%	32.1%	34.9%
Rivers	46,054	19,480	37,144	15,723	523,394	283,383
	35.4%	36.8%	40.0%	36.0%	24.0%	21.6%
Southern area	14,171	5,972	19,828	11,180	317,104	218,918
	10.9%	11.3%	21.4%	25.6%	14.5%	16.7%
Total	130,175	52,915	92,774	43,645	2,182,853	1,313,054
	6.0%	4.0%	4.3%	3.3%	100.0%	100.0%

Note: Albemarle area includes all inside waters designated the Albemarle Sound Management Area (ASMA) from the Virginia-North Carolina line, including Currituck Sound, the Albemarle Sound and all tributaries, Croatan Sound, and Roanoke Sound to the south end of Roanoke Marshes across to Eagle Nest Bay, below Oregon Inlet. Ocean includes all ocean waters of North Carolina. Pamlico area includes all water south of the ASMA line and Core Sound to Beaufort inlet including the Newport River. The Rivers include the New, Neuse, Pamlico, and Pungo Rivers. The Southern area designation for the state includes all inside waters on the southside of Beaufort Inlet, Bogue Sound, Topsail Sound, and the Cape Fear River to the North Carolina-South Carolina line.

Trip/ Vessel Harvest Limits

Trip or vessel harvest limits may not work well for the striped mullet commercial fishery because a majority of the landings are taken in a very short period of time. Mixed market grade harvest occurs year-round, although more heavily in late summer to early fall and in January, probably associated with increased availability due to schooling during these months (Figure 4). Ninety-eight percent of the annual red roe harvest and 94% of the white roe harvest occurs in October and November (Figure 5). Most spawning striped mullet will be graded as mixed after Thanksgiving, even though ripe fish are occasionally harvested into February-March. The roe market shifts from North Carolina to Florida in December. Most documented trips in the striped mullet fishery are composed of small catches. Seventy percent of the total number of striped mullet trips between 1994-2002 were composed of catches with less than 100 lb of landed striped mullet (Figure 5). Small harvest trips (< 100 lb) are less frequent in the peak months of October and November implying an increased directed effort for striped mullet during these months. Trips with less than 100 lb of striped mullet harvest accounted for approximately 10% of the total landings in weight between 1994-2002 (Figure 5). Furthermore, catches with less than five lb of striped mullet harvest were the most common trip type, accounting for 21% of total trips.

Pronounced year-to-year fluctuations in red roe harvest are evident from 1994 to 2002. Strong weather conditions (hurricanes, cold fronts) during the fall can profoundly affect annual landings. In addition to limiting fishing opportunities, hurricanes and high winds can cause spawners to exit inshore areas rapidly and prematurely. Hurricanes

Fran and Floyd likely depressed landings in 1996 and 1999. A trip or vessel harvest limit would prevent fishermen from taking advantage of periods of large catches due to wind and storm events, reducing the productivity and availability of fishermen to make a living. Discards will increase if trip harvest limits are imposed.

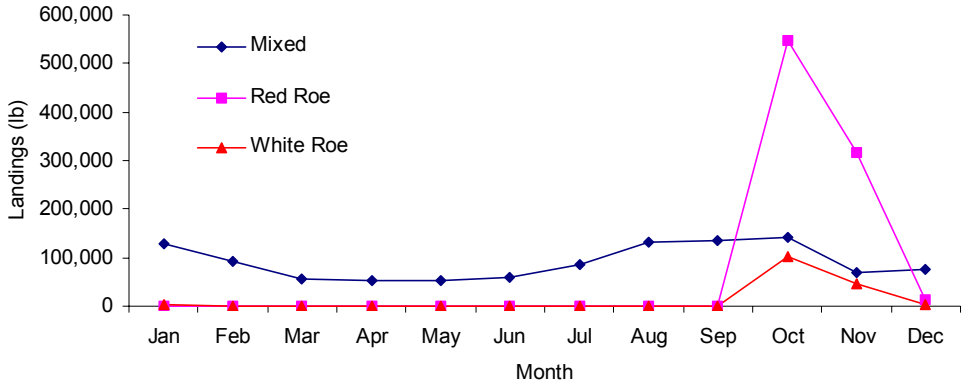

Figure 4. Average monthly commercial landings of striped mullet in major market categories (1994-2002).

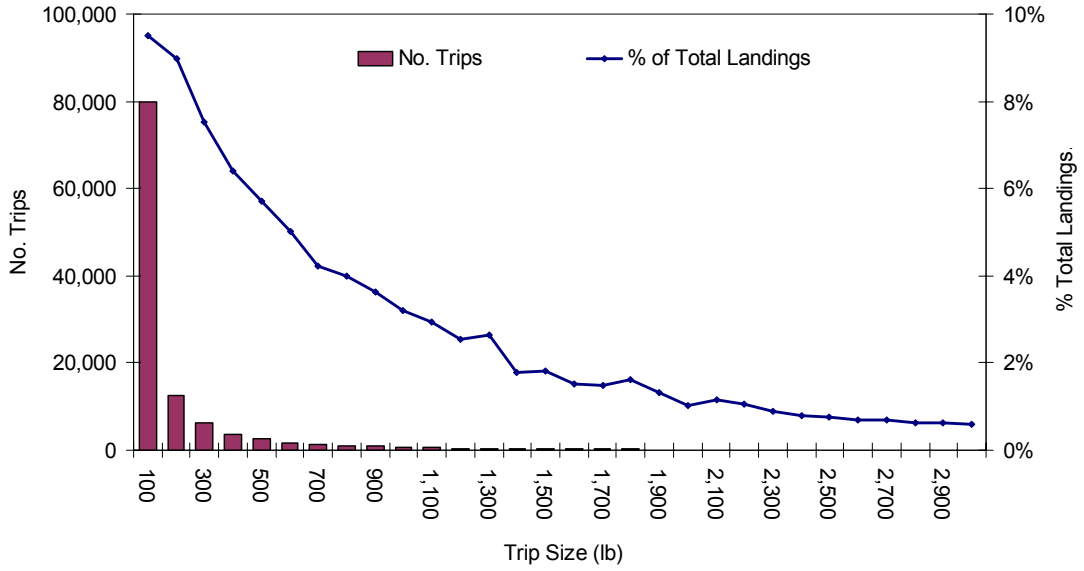

Figure 5. Total number of trips in each 100 pound size class of harvest and its percentage of the total commercial landings (1994-2002).

Gear Restrictions

An average of 92% of annual mullet commercial landings are harvested by gill nets (runaround, set, and float nets). Runaround gill nets account for 49% of the harvest, followed by set nets (combined sink and float gears) at 42 % (1994-2002 landings data). On average, beach seines were responsible for 5.4% of the annual harvest, and cast nets yielded 1.1% from 1994 to 2002. Gill nets are the only major gear in which restrictions would have the most impact in reducing harvest. There are two

components to gill net gear restrictions that could occur: mesh size restrictions and net length limits.

The runaround gill net fishery targets striped mullet, and operates year-round with most of the effort occurring from September through November when prices are high due to increased roe content of spawning females. Nets are typically 100 - 1000 yd. in length with a stretched mesh of 3 ½ to 4 ½ inches (see Bycatch Assessment of Striped Mullet (*Mugil cephalus)* in North Carolina Fisheries issue paper). Soak times for this fishery are typically less than four hours and nets are attended during the entire operation.

Target species in the set gill net fishery (shallow water, small mesh) include, spot, striped mullet, spotted seatrout, weakfish, and bluefish. Nets are anchored overnight similar to the large mesh fishery for flounder that occurs in the same area. Each fishing operation sets 500 to 3,000 yards of small mesh (3 to 4 ½ inch) gill net, which are retrieved by hand and net reels (see Bycatch Assessment of Striped Mullet (*Mugil cephalus)* in North Carolina Fisheries issue paper). In recent years, the DMF has enacted rules designating small mesh (< 5 inch stretched) attendance areas from March 1 through October 31 to minimize red drum bycatch and subsequent discard mortality (Rule 15A NCAC 3J .0103 (h) in NCMFC 2002). This rule requires small mesh gill net fishermen to remain within 100 yards of their net at all times.

IV. CURRENT AUTHORITY

15A NCAC 3M .0502 MULLET

The Fisheries Director may, by proclamation, impose any or all of the following restrictions on the taking of mullet:

(1) Specify season,
(2) Specify areas,
(3) Specify quantity,
(4) Specify means/methods,
(5) Specify size.

V. MANAGEMENT OPTIONS/IMPACTS

(+ Potential positive impact of actions)
(- Potential negative impact of actions)

1. Status quo
   + No rule changes or Legislative actions
   + No additional restrictions on fishing practices
   + No additional burden to law enforcement
   - Possibility of overharvesting in the future resulting in an overfished stock status

2. Re-assess stock status on a yearly basis using data -based criteria
   + Proactive management measure
   + Addresses uncertainty in the stock assessment model
   - Yearly analysis may be time consuming
   - Uncertainty in defining effective triggers

3. Implementation of Regulations

a. Quotas

+ Controls harvest levels
- Not sensitive to fluctuations in recruitment or availability of fish to the fishery
- Additional reporting burden to commercial dealers
- Requires additional resources from DMF to implement
- May restrict harvest more or less than necessary
- Overfishing may still occur if recruitment is minimal
- Potential to go over quota due to short period of high landings.

b. Limited Entry

+ Prevent growth of the fishery
+ Protects historical participants in the fishery
- Will not restrict individual increases in effort
- Overfishing may still occur

Cannot be considered for action unless there is no other means of achieving the target fishing mortality levels (sustaninable harvest).

c. Size Limits

+ Reduces the number of smaller or larger fish caught
- Reduces the number of smaller or larger fish harvested in the catch
- Increase the burden on law enforcement
- Increase discards
- Change selectivity of commercial fishery

d. Season or Area closures

1. Season closures

+ No additional resources required to implement
+ No reporting burden on fishermen or dealers
+ Reduces effort from current level
- Forces fishermen to search for other sources of income
- Weather may prevent fishing during open periods
- Reducing fishing mortality at or below F_{Target} may not be achieved
- Increase the burden on law enforcement
- Increase discards during the closed season

2. Area closures

+ No additional resources required to implement
+ Reduces effort from current level
+ No reporting burden on fishermen or dealers
- Forces fishermen to search for other sources of income
- Weather may prevent fishing during open periods
- Effort may be increased during the open periods in other areas, thus reducing the effectiveness of the closure
- May adversely impact some fisheries and fishermen more than others
- Increase the burden on law enforcement
- Increased discards

e. Trip/Vessel Harvest Limits
+ Reduces effort in the fishery
- Increase discards
- May adversely impact some fisheries and fishermen more than others.
- Would not guarantee reduction of fishing mortality to the target level
- Increase the burden on law enforcement

f. Gear restrictions
1. Mesh size restrictions
+ Will reduce the number of smaller or larger fish caught
- Will reduce the number of smaller or larger fish harvested in the catch
- Increase the burden on law enforcement
- Change selectivity of commercial fishery

2. Net length restrictions
+ Maintains effort at a consistent level for each participant
+ Reduces the amount of nets in the water
- Some areas of the state may be more heavily impacted than others
- Increase the burden on law enforcement

VI. RECOMMENDATIONS

DMF Recommendation:

Status quo and establish triggers for re-assessment. Implement no new management measures at this time but establish minimum and maximum landings thresholds of 1.3 million pounds and 3.1 million pounds, respectively. If landings fall below the minimum threshold the DMF would initiate further analysis of the data to determine if the decrease in landings is attributed to stock decline or decreased fishing effort. If landings exceed the 3.1 million pounds the DMF would initiate analysis to determine if harvest is sustainable and assess what factors are driving the increase in harvest.

Advisory Committee Recommendation:

The AC endorsed the DMF recommendation.

VII. RESEARCH NEEDS

1. Continue annual age determination and creation of age-length keys.
2. Validate juvenile abundance indices.
3. Annual review of commercial and recreational fisheries.

11.5 Appendix 5 PIER, STOP NET AND GILL NET FISHING CONFLICTS IN THE ATLANTIC OCEAN

I. ISSUE

User conflicts in the Atlantic Ocean striped mullet beach seine fishery have existed along Bogue Banks since the mid 1980s and have involved allocation issues between commercial gill netters and the stop net crews, and between the ocean fishing pier owners, pier patrons and the stop net crews. Although not as intense as in years past, these confrontations still occur.

II. BACKGROUND

The beach seine striped mullet fishery is described in the Commercial Fishery section of the FMP. With the continuing development of Bogue Banks, increased tourism, recreational fishing along the beach and on public fishing piers and more gill net effort, the beach seine/stop net roe mullet fishery has been the focus of controversy for over twenty years. Complaints have involved space and resource allocation issues and have pitted the stationary fishing piers and stop nets and the more mobile gill netters against each other.

Confrontations have generally been divided into three categories: Stop nets vs. ocean fishing piers; stop nets vs. gill nets; and stop nets vs. recreational beach fishermen and beach residents. An aspect of the last category involved the use of spotter aircraft for directing the stop net crews where and when to set the seine or "strike" on a school of migrating striped mullet. Most recently, the dolphin interactions with stop nets and gill nets have been the subject of federal scrutiny and proposed actions (see Management Implications of Proposed NMFS Beach Seine and Stop Net Regulations on Bottlenose Dolphin issue paper).

Ocean pier owners have long complained that the setting of stop nets along Bogue Banks east of their piers impeded or stopped the migration of non-mullet species such as spot, spotted seatrout, pompano, red drum, etc. and prevented them from reaching their patrons fishing on the piers.

Gill netters and stop netters have historically been at odds over the allocation of the schools as they come down the beach. The mobile gill netters have set in front of and even within the stop nets, and the beach seiners are accused of harvesting an inordinate amount of the resource. In the mid-1980s, the use of spotter aircraft to direct the beach seiners when to strike the striped mullet schools was deemed unfair by gill netters and recreational fishermen alike. The vehicular traffic on the beach associated with stop nets (pickup trucks and tractors) is a source of controversy with beachfront residents, sea turtle activists and recreational fishermen.

The Division of Marine Fisheries (DMF) has responded to these complaints, educated the parties on how the fishery was carried out, cited the guiding rules and regulations and mediated compromises among the users that have improved the situation to this point.

III. DISCUSSION

Following are descriptions of some of the major confrontations between stop net crews and other entities and how these situations were dealt with.

In the fall of 1984, complaints were received that the striped mullet beach seine crews were using aircraft as spotter planes to alert the stop net crews of the location of migrating schools of striped mullet going down the beach. Gill netters claimed that spotting with aircraft gave the beach seine crews an unfair advantage over them. Public support for banning the spotter planes resulted in 1989 legislation prohibiting their use for food fish (G.S. 113-171).

The complaints and problems associated with the owners and patrons of ocean fishing piers vs. stop nets escalated until 1993. In that year, the DMF conducted a study to determine the effects of stop nets on fish migration and pier and beach angler catch rates (NCDMF 1994). Although the results showed that the use of stop nets had no significant affect on pier and beach angler catch rates, the public remained skeptical. Frequent meetings with pier owners and stop net crew representatives were held separately and then mediation was arranged with both groups together. These talks resulted in self-imposed restrictions that the stop netters and pier owners thought would reduce the conflict. These agreements were formalized into elements of a proclamation issued by the Fisheries Director in the fall of 1994. These restrictions specified six stretches of beach along Bogue Banks where a maximum of four stop nets could be set by the two crews at any one time. Stop net use was allowed only during October and November. Stop nets were restricted to a length of 400 yards and could not be any closer than 880 yards to another stop net. Large mesh (6 and 8 inch stretched mesh) was required for the stop nets to allow the passage of non-mullet species. These restrictions, with little change, have been in place since then and have reduced the conflict considerably.

In late 2001, several gill net crews began setting their sink nets in close proximity to the ocean piers and the stop nets. In some cases they set their gill nets so as to function as a stop net. No rules or proclamations prohibited these sets and the pier owners and the stop netters combined forces to protest these activities. The Fisheries Director has authority over gill nets and seines but wanted the Marine Fisheries Commission (MFC) to address the issue holistically. The pier owners submitted a petition for rulemaking to prompt this action. Just prior to the MFC meeting at which this issue was to be addressed, the opposing groups were brought together by DMF staff and an agreement was reached that brought resolution to this localized problem, without penalizing all gill nets statewide. The restrictions put in place by proclamation in fall of 2001 included a maximum gill net length, a minimum distance between gill nets, an exclusion zone from 150 yards off the beach to 350 yards offshore in which no gill net can be set, a 250 yard minimum distance between fishing piers and gill nets and a minimum distance of 450 yards east from where a deployed stop net is set to where gill nets were permitted. These restrictions have been in place since then and prevented the reoccurrence of problems so far.

During the December, 2004 striped mullet Advisory Committee (AC) meeting, it was brought to our attention that several incidents of gill netters striking within the three stop nets west of the regulated zone (Raleigh Street to Bogue Inlet) had occurred this fall. The AC urged the DMF to mediate this situation with the two parties and see if a

distance can be established to separate the two groups. A distance of 950 yards was suggested.

Complaints of excessive vehicular traffic, litter and alcohol abuse have decreased dramatically due to efforts by the stop net crews to police themselves and educate the public spectators and recreational fishermen they encounter during their sets. Attempts by the recreational sector to prohibit the crew's pickup trucks on the beach were unsuccessful because a general statute that specifically states that commercial fishermen's vehicles shall not be prohibited. Recreational fishermen find the area east of the stop nets productive fishing spots and are not discouraged by the crews. Tourists often find the launching and retrieval of the beach seine very interesting and educational.

With the Asian economic recession, the market for roe mullet has declined in the past few years. Low prices, in combination with beach nourishment activities, younger people not entering fishing, older fishermen aging out of the fishery, restrictions placed on the stop net and gill net fisheries, and other factors have reduced the scale of beach seine/stop net operations significantly. The perception and allocation problems associated with this fishery in the past have largely been resolved through cooperation, education, regulation and time.

IV. CURRENT AUTHORITY

G.S. 113-182 Regulation of fishing and fisheries
G.S. 113-171.1 Spotter Plane Use for Food Fish
G.S. 106A-308 Vehicle Use on Beaches
15A NCAC 03I .0108 Ocean Fishing Pier Marking
15A NCAC 03J .0101 Fixed or Stationary Nets
15A NCAC 03J .0103 Gill Nets, Seines, Identification, Restrictions
15A NCAC 03J .0402 Fishing Gear Restrictions
15A NCAC 03M .0503 Mullet

V. MANAGEMENT OPTIONS/IMPACTS

(+ Potential positive impact of actions)
(- Potential negative impact of actions)

1. Status quo – permit the fishery to exist under current proclamation authority
   + present restrictions have addressed conflicts
   + those restrictions will limit growth if the value of the fishery increases again
   - requires proclamation be issued annually
   - change in leadership could affect that use of proclamation authority

2. Adopt current proclamation management measures in rule
   + establishes a more long-term reliable management strategy
   + provides readily accessible information source for users
   - present situation affects only a few fishermen
   - current management addresses conflicts
   - new federal MMPA requirements will require management modifications

VI. RECOMMENDATIONS

DMF Recommendation:

Adopt current gill net restrictions on Bogue Banks that currently are in proclamation as Rule. These measures were put in place in 2001 and seem to be effective. It is premature to put the stop net proclamation measures into Rule because of the upcoming NMFS Bottlenose Dolphin Take Reduction Plan restrictions and the changing nature of the beach seine mullet fishery. Flexibility needs to be maintained for stop net setting sites and gear parameters.

Address the new conflict between gill netters and stop netters at the three western Bogue Banks stop nets with a minimum distance requirement. The distance of 950 yards was suggested by the AC.

Advisory Committee Recommendation:

Adopt the current proclamation concerning gill net placement on eastern Bogue Banks into a Rule. Also address the three western Bogue Banks stop net sets vs. gill netters recent controversy by gathering the stop net crew and gill netter representatives and discussing a minimum distance between deployed stop nets and gill net operations east of them. The distance of 950 yards was suggested.

Based on the development in April 2006 of the sale of two of the three ocean fishing piers that are the subject of the proclamation to be incorporated into Rule, the DMF now recommends that the proclamation not be adopted as Rule. This would allow the Director to retain the flexibility to address with proclamation authority any situations that may arise. Enacting a Rule, which cannot be changed in a timely manner, would restrict actions needed in the immediate future. The Striped Mullet Advisory Committee was contacted by mail and email to inform them of the change in the DMF recommendation and solicit their thoughts. Only Doug Guthrie, stop net crew representative, responded and he agrees with the change.

VII. LITERATURE CITED

NCDMF 1994. Effect of stop nets on pier and beach angler catch rates and general fish movement along Bogue Banks, NC. North Carolina Department of Environment, Health, and Natural Resources, Division of Marine Fisheries. 17pp.

11.6 Appendix 6 INSHORE STRIPED MULLET GILL NET FISHING CONFLICTS

I. ISSUE

The change in inshore striped mullet fishing practices from traditional, passive soak nets to tower boats and runaround nets has created conflicts with marinas and shoreline residents. Setting of gill nets around private piers and in restricted navigation areas and disruptive practices associated with night fishing have resulted in charges against the striped mullet fishermen of impeding navigation and disturbing the peace. The situation has resulted in petitions for rulemaking asking the Marine Fisheries Commission (MFC) for varying degrees of gill net exclusion from specific areas.

II. BACKGROUND

Traditional striped mullet fishing practices involve setting gill nets or stop nets in known fall migration routes during weather conditions that trigger offshore movement of striped mullet. Higher prices for roe mullet and the prohibition of gill net use in some states brought striped mullet fishermen and new fishing practices to North Carolina. The new striped mullet fishing practices involve searching for striped mullet in boats with raised platforms for increased visibility and setting runaround gill nets to trap or encircle the fish. Local fishermen have adopted the more aggressive striped mullet fishing techniques. Striped mullet are a forage species that is hunted for food by many predators, so striped mullet seek protective cover. The runaround gill nets can be set on migrating fish found in open waters or on fish found around structure, which tends to attract fish that are not migrating.

This tendency of striped mullet to congregate around protective structure has resulted in requests for regulatory action in marinas and heavily populated creeks. Striped mullet fishermen, often at night, set their gill nets around marina owned and private docks creating documented navigation conflicts. Additionally, fishermen create a disturbance to frighten the fish into leaving the protective cover. These disturbances have been reported as beating on boats and docks, loud engine noise, slapping the water with oars, using explosives and shining spotlights into residences. Trespassing complaints have also been made as fishermen have entered onto docks and into yards along bulkheads searching for striped mullet.

Weather events causing the striped mullet to move offshore en masse before the prime roe season and poor market conditions have led to reduced effort recently and conflicts have been minimal. Previously, the MFC took action on requests for rulemaking from two conflict areas in Carteret County and one in Pender County. In each case, the MFC attempted to resolve the conflicts yet still allow access to the striped mullet in some portions of the affected area or during particular times when the potential conflicts would be reduced. In one case, the MFC chose to place in rule provisions that were already addressing the conflict through proclamation authority.

III. DISCUSSION

15A NCAC 03J .0402 Fishing Gear Restrictions - is the rule that contains provisions that address fishing gear conflicts. With the exception of waters immediately adjacent to State Parks, licensed fishing piers and the Cape Lookout rock jetty, all of the areas closed to the use of gill nets and seines in 03J .0402 have some time or gear size

restrictions that allow gill net/seine fishing at some time of the year or with specific gear configurations. These restrictions were initially implemented under proclamation authority as past Fisheries Directors attempted to resolve user conflicts. Since typical recreational and navigational uses are low at certain times of the year, commercial fishing activities continued to be allowed during those periods when conflict would be at a minimum.

The result of these actions is consistent with the General Assembly's charge to conservation agencies to be stewards of marine and estuarine resources and to manage those resources for the benefit of the people of the state as a whole. The MFC is authorized to regulate the placement of nets in coastal fishing waters to preserve navigational or recreational safety but they are also charged with maintaining access to public trust resources.

Petitioners typically request a 24 hour 365 day per year ban on gill net fishing for the entire waterbody to resolve their concerns. They often cite depletion of local fish stocks, interference with navigation, trespassing and disturbing the peace as the reasons for the closure. The Division of Marine Fisheries (DMF) and the MFC manage fish stocks based on the health of the entire North Carolina population of that species of fish, not on numbers of fish in a local creek. The numbers of fish in a particular creek may be temporarily reduced due to commercial or recreational fishing pressure or natural causes. Local population fluctuations are not necessarily a sign that stocks are in trouble and local residents cannot expect to control a portion of a resource that, until captured, belongs to the people of North Carolina as a whole. Interference with navigation has been a problem and portions of the existing rules on this matter have seasonal closures in access channels during high use seasons. However, complete gill net bans are not required and it is always unlawful to set stationary gill nets so as to block more than two-thirds of any natural or manmade waterway, sound, bay, creek, inlet or other body of water, or in any location where it may constitute a hazard to navigation. Trespassing and disturbing the peace are not matters under the jurisdiction of the MFC and it is not appropriate to use fisheries rules to solve those problems. Local law enforcement is responsible for enforcing the provisions of those laws.

IV. CURRENT AUTHORITY

G.S.113-182 Regulation of fishing and fisheries
15A NCAC 03J .0101 Fixed or Stationary Nets
15A NCAC 03J .0103 Gill Nets, Seines, Identification, Restrictions
15A NCAC 03J .0402 Fishing Gear Restrictions

V. MANAGEMENT OPTIONS/IMPACTS

(+ Potential positive impact of actions)
(- Potential negative impact of actions)

1. Status Quo [Continue to handle inshore gill net conflicts on a case-by-case basis and implement management actions to address specific fishery related problems]
   + Maintains maximum access for all fisheries
   + Minimizes restrictions
   + Provides capability to tailor restrictions to varying situations
   - Does not address all residential concerns
   - Time consuming and piece meal

2. Adopt 24 hour, 365 day per year gill net closures for high density residential and tourist developments on request
   + Addresses all of the resident's concerns
   + Provides for easy identification of violators and efficient enforcement
   - Will likely result in most developed areas requesting a gill net ban
   - Deprives SCFL and RCGL holders of access to the resource
   - Restricts all gill netters because of the actions of a few
   - Time consuming and piece meal

3. Survey water use patterns and designate broad areas as gill net prohibited areas
   + Addresses the problem in a comprehensive fashion
   + Provides for easy identification of violators and efficient enforcement
   - Deprives SCFL and RCGL holders of access to the resource
   - Restricts all gill netters because of the actions of a few
   - Increases the burden on gill net fishermen

4. Cease taking any action in proclamation or new rules and use existing rules to manage gill net conflicts
   + Reduces the regulatory burden on gill net fishermen
   - Does nothing to address area specific conflicts
   - Will escalate confrontations between problem gill netters and residents

VI. RECOMMENDATIONS

DMF Recommendation:

Status Quo [Continue to handle inshore gill net conflicts on a case-by-case basis and implement management actions to address specific fishery related problems].

Advisory Committee Recommendation:

Status Quo [Continue to handle inshore gill net conflicts on a case-by-case basis and implement management actions to address specific fishery related problems].

11.7 Appendix 7 MANAGEMENT IMPLICATIONS OF PROPOSED NMFS BEACH SEINE AND STOP NET REGULATIONS ON BOTTLENOSE DOLPHIN

I. ISSUE

Division of Marine Fisheries (DMF) staff, ocean fishing pier operators and the striped mullet beach seine/stop net crews reached agreement in 1994 on specific stop net mesh sizes and placement to alleviate real and perceived problems between pier patrons and striped mullet fishermen concerning migration of fish along the beach. Those agreed upon mesh sizes would be illegal under measures proposed by the National Marine Fisheries Service (NMFS) in November of 2004.

II. BACKGROUND

From 1993 to 1999, the Cetacean and Sea Turtle Team of the NMFS, Beaufort, NC Laboratory reported approximately eight bottlenose dolphin (*Tursiops truncatus)* strandings associated with stop nets on Bogue Banks. Strandings are rare in this fishery, but they do occur occasionally. Due to the reduced dolphin populations and the frequent interaction between dolphins and some types of fishing gear along the entire Atlantic coast, the NMFS convened the Bottlenose Dolphin Take Reduction Team (TRT). This group met five times from April 2001 to November 2002 to develop recommendations for a Take Reduction Plan for the western Atlantic coastal bottlenose dolphin. In May of 2002, the TRT reached consensus on recommendations for the major fisheries that they believe will bring the take of dolphin below "potential biological removal" (PBR) levels for the coastal stocks. The PBR is the estimated number of individuals that can be removed from a marine mammal stock that will not have a detrimental effect on the stock. New dolphin population abundance figures became available after that and the TRT met once again in April of 2003, producing updated recommendations.

Those recommendations that pertained to North Carolina beach-based fishing practices defined beach haul seines as any gear attached, anchored to, or fished from the beach and said that they must use 4" stretched mesh or less. For roe mullet stop nets, it was any gear attached, anchored to, or fished from the beach must use 4" stretched mesh or less, with the exception that up to the first 100 yards of net from the shoreline may be up to 8" stretched mesh. In April of 2003, the TRT was reconvened after NMFS determined that the May 2002 recommendations would not reduce dolphin mortalities below PBR. At the 2003 meeting, the TRT amended the initial recommendation on roe mullet stop nets to say that they should "be required to abide by the 4" (or less) multi-fiber nylon stretched mesh webbing requirement for the entire stop net and the seine used to harvest from the stop net".

In November of 2004, NMFS published a Proposed Rule for a Bottlenose Dolphin Take Reduction Plan (50 CFR Parts 223 and 229; November 10, 2004). The TRT recommendations served as the basis for the proposed rule. Public comment on the proposed rule was solicited in the public notice and was accepted by NMFS through February 8, 2005.

III. DISCUSSION

In 1994, the DMF implemented mesh size restrictions for the stop net roe mullet fishery on Bogue Banks that have been in place ever since. The striped mullet crews originated the concession to alleviate some of the concerns of the ocean fishing pier owners and patrons that the schools of spot, pompano, weakfish and other recreationally important fish are corralled by the stop nets and kept from proceeding along the shore to the west. Currently, the inshore 100 yards of a stop net must be constructed of webbing a minimum of 8" (stretched mesh) and the offshore 50 yard portion must be constructed of webbing a minimum of 8 inches. The remaining middle section of the net must be of 6" webbing. This configuration still impedes the roe mullet schools so the fishery can function and allows the passage of other fish along the beach.

The proposed rule that primarily impacts the striped mullet stop net fishery reads, "No person may fish with a net within 300 feet (91.4m) of the beach/water interface unless it consists of multi-fiber nylon (no type of monofilament material) that is 4 inches (10.2 cm) or less stretched mesh." This proposal will prohibit mesh sizes greater than 4 inches for the beach seine and roe mullet stop net fisheries. Under the federal Marine Mammal Protection Act, the NMFS is authorized to implement rules in state waters to protect dolphins and other threatened and endangered mammals.

This not only has the potential to revive the conflict between the pier fishermen and the mullet crews, but will force the members of the crew to have to retire these expensive nets and have new ones constructed of mesh that comply with the new rule. Estimates for replacing the six nets used by the Bogue Banks stop net fishing crews are $9,000 per net for a total of $54,000. The larger mesh stop nets currently in use also reduce gilling of red drum and entanglement of sharks. This increased bycatch and damage will increase with the 4 inch mesh requirement.

IV. CURRENT AUTHORITY

15A NCAC 3M .0502 MULLET

The Fisheries Director may, by proclamation, impose any or all of the following restrictions on the taking of mullet:

(1) Specify season,
(2) Specify areas,
(3) Specify quantity,
(4) Specify means/methods,
(5) Specify size.

15A NCAC 3J .0103 GILL NETS, SEINES, IDENTIFICATION, RESTRICTIONS

(a) It is unlawful to use a gill net with a mesh length less than 2½ inches.

(b) The Fisheries Director may, by proclamation, limit or prohibit the use of gill nets or seines in coastal waters, or any portion thereof, or impose any or all of the following restrictions on the use of gill nets or seines:

(1) Specify area.
(2) Specify season.
(3) Specify gill net mesh length.
(4) Specify means/methods.
(5) Specify net number and length.

(c) It is unlawful to use fixed or stationary gill nets in the Atlantic Ocean, drift gill nets in the Atlantic Ocean for recreational purposes, or any gill nets in internal waters unless nets are marked by attaching to them at each end two separate yellow buoys which shall be of solid foam or other solid buoyant material no less than five inches in diameter and no less than five inches in length. Gill nets, which are not connected together at the top line, shall be considered as individual nets, requiring two buoys at each end of each individual net. Gill nets connected together at the top line shall be considered as a continuous net requiring two buoys at each end of the continuous net. Any other marking buoys on gill nets used for recreational purposes shall be yellow except one additional buoy, any shade of hot pink in color, constructed as specified in Paragraph (c) of this Rule, shall be added at each end of each individual net. Any other marking buoys on gill nets used in commercial fishing operations shall be yellow except that one additional identification buoy of any color or any combination of colors, except any shade of hot pink, may be used at either or both ends. The owner shall always be identified on a buoy on each end either by using engraved buoys or by attaching engraved metal or plastic tags to the buoys. Such identification shall include owner's last name and initials and if a vessel is used, one of the following:

(1) Owner's N.C. motor boat registration number, or
(2) Owner's U.S. vessel documentation name.

(d) It is unlawful to use gill nets:

(1) Within 200 yards of any pound net set with lead and either pound or heart in use;
(2) From March 1 through October 31 in the Intracoastal Waterway within 150 yards of any railroad or highway bridge.

(e) It is unlawful to use gill nets within 100 feet either side of the center line of the Intracoastal Waterway Channel south of the entrance to the Alligator-Pungo River Canal near Beacon "54" in Alligator River to the South Carolina line, unless such net is used in accordance with the following conditions:

(1) No more than two gill nets per boat may be used at any one time;
(2) Any net used must be attended by the fisherman from a boat who shall at no time be more than 100 yards from either net; and
(3) Any individual setting such nets shall remove them, when necessary, in sufficient time to permit unrestricted boat navigation.

(f) It is unlawful to use drift gill nets in violation of 15A NCAC 03J .0101(2) and Paragraph (e) of this Rule.

(g) It is unlawful to use unattended gill nets with a mesh length less than five inches in a commercial fishing operation in the gill net attended areas designated in 15A NCAC 03R .0112.

(h) It is unlawful to use unattended gill nets with a mesh length less than five inches in a commercial fishing operation from May 1 through October 31 in the internal coastal and joint waters of the state designated in 15A NCAC 03R .0112.

V. MANAGEMENT OPTIONS/IMPACTS

(+ Potential positive impact of actions)
(- Potential negative impact of actions)

1. Status Quo – continue to use 6 and 8 inch multifilament webbing
   + save time and expense of constructing new nets
   + controversy with piers and beach recreational fishermen remains calm
   + reduced bycatch and shark entanglement with large mesh
   - beach seines and gill nets in violation will be removed and fishing by all these gears could be closed down

- contentious relations with NMFS over noncompliance with MMA and ESA.

2. Adhere to new federal rules
   + allows beach seine fishery to continue
   - may revive ocean fishing pier, beach recreational fishermen controversy
   - increased red drum bycatch and shark related net damage with 4 inch mesh.
   - increased financial burden on stop net crews to replace gear

3. Encourage fishermen to seek federal funding for conversion of stop nets to legal mesh size
   + fishermen not penalized for having to reduce mesh sizes agreed to in the past for reducing conflict
   + fishermen able to continue fishing due to ability to pay for conversion
   - may result in other beach seine and gill net conversion requests
   - federal funding source unknown

4. Explore possibility of a federal buyout of Bogue Banks stop net fishery
   + fishermen compensated for expensive nets and equipment
   - fishermen no longer able to pursue winter livelihood and cultural activity in existence for over a century
   - federal funding source unknown

VI. RECOMMENDATIONS

DMF Recommendation:

Fishermen should explore possibility of federal funding source for the conversion of the Bogue Banks mullet stop nets from the 6 and 8 inch mesh to the soon-to-be-legal maximum of 4 inch.

The Advisory Committee and the Division of Marine Fisheries should submit comments to NMFS by the February 8, 2005 deadline that highlight the cost of converting mesh size, revived social conflict with ocean fishing piers, and the potential for increased shark and red drum entanglement in the smaller meshed stop nets (see Supplement 1 for DMF comments; Supplement 2 for MFC comments).

Following public meetings and the presentation to the Joint Legislative Commission on Seafood and Aquaculture, the DMF recommendation was changed to determine what the federal regulations resulting from the Bottlenose Dolphin Take Reduction Plan were and react accordingly. This requires no state action.

Advisory Committee Recommendation:

The Advisory Committee opposed the proposed NMFS gill net marking requirements in internal waters, stating that the present North Carolina requirements were adequate. The AC recommended that fishermen be allowed to mark their nets in oceanic waters using an identification tag and/or other means of permanent identification such as a permanent marker every 100 yards to identify the state vessel registration number, Coast Guard documentation number or the state commercial fishing license number. The AC recommended that monofilament gill net less than or equal to five inches be allowed within 100 yards of the beach

in North Carolina as long as it is attended. This would allow the roe mullet gill net fishery to exist.

Supplement 1. North Carolina Division of Marine Fisheries comments on the proposed rules for the Taking of Marine Mammals Incidental to Commercial Fishing Operations; Bottlenose Dolphin Take Reduction Plan.

February 8, 2005

David Bernhart, Chief
Protected Resources Division
NMFS/SERO
9721 Executive Center Drive North
St. Petersburg, FL 33702-2432

Dear Mr. Bernhart:

The North Carolina Division of Marine Fisheries (NCDMF) provides the following comments on the Proposed Rules for the Taking of Marine Mammals Incidental to Commercial Fishing Operations; Bottlenose Dolphin Take Reduction Plan; Sea Turtle Conservation Restrictions to Fishing Activities (Proposed Rules) identified in RIN 0648-AR39 dated November 10, 2004.

Proposed Rule: Gear-area Measures - *Summer Northern North Carolina, Summer Southern North Carolina, and Winter Mixed MU's (North Carolina coast-wide), p. 65132 and* Table 3 Gear Operating Requirements.

The proposed prohibition of the use of monofilament webbing within 300 feet of the beach was never the intention of the Bottlenose Dolphin Take Reduction Team (TRT) and was not a TRT consensus recommendation from either the May 2002 or April 2003 meetings. The intention of the TRT recommendations was to address bottlenose dolphin takes in monofilament gear used in the North Carolina beach seine fishery for striped bass. The TRT met January 13-14, 2005 and reached consensus on recommendations that they believe will reduce bottlenose dolphin interactions with beach seine and monofilament gill net gear and minimize the unintended impact on traditional beach based fisheries. The NCDMF is opposed to the proposed prohibition of monofilament webbing within 300 feet of the beach because of the unintended impact that the prohibition will have on a number of our fisheries. The NCDMF supports the consensus recommendations that were developed at the January 2005 meeting of the TRT. We recommend implementation of these measures rather than the proposed prohibition of monofilament webbing within 300 feet of the beach.

Consensus recommendations from the January 13-14, 2005 TRT meeting:

"All monofilament gear deployed from, fished from, or landed on the beach must be small mesh (less than five inches). Such gear must be attended at all times, be actively fished, and the body and both ends of the net be landed on the beach. This prohibition does not apply to vessels launched from the beach that set their gear more than 100 yards from the beach."

"Beach seines fished north of Cape Lookout, North Carolina during the Atlantic Ocean striped bass beach seine fishery established by the North Carolina Division of Marine

Fisheries by proclamation, shall be constructed of only multi-filament or multi-fiber webbing with a maximum mesh size less than seven inches stretched mesh, and shall be actively fished."

The NCDMF does not support language in the January 2005 TRT consensus recommendation that will require the inshore 300 foot portion of a roe mullet stop net to be constructed of webbing with a maximum mesh size of four inches or less stretched mesh.

Consensus recommendation from the January 13-14, 2005 TRT meeting:

"Beach seines and stop nets fished south of Cape Lookout, North Carolina during the roe mullet stop net fishery established by the North Carolina Division of Marine Fisheries by proclamation, to be constructed of only multi-filament or multi-fiber webbing with a maximum mesh size of four inches or less stretched mesh for the entire seine net, and the inshore 300 foot portion of the stop net, except the seine net shall be actively fished."

This recommendation would require that the inshore 300 feet of a stop net be constructed of multi-filament or multi-fiber webbing with a maximum mesh size of four inches or less stretched mesh. In the roe mullet beach seine fishery, the seine and the stop net is traditionally constructed of multi-filament or multi-fiber webbing. Since 1993, the NCDMF has required that the inshore 300 feet of a stop net be constructed of eight inch stretched mesh webbing. The NCDMF implemented the requirement for eight inch webbing in the inshore portion of a stop net as a compromise between commercial roe mullet fishermen, pier owners and recreational fishermen. The 300 foot inshore section of eight inch webbing is intended to allow species that are of interest to pier fishermen, spot, red drum, spotted sea trout, etc., to pass through the stop net. The switch to four inch webbing in the inshore 300 feet of the stop net will undermine the compromise between commercial fishermen and the recreational sector that has worked well for more than ten years.

The NCDMF is also concerned that the use of four inch webbing in the inshore portion of stop nets will result in increased bycatch of stressed or overfished species. Red drum, southern flounder, and bluefish are showing signs of recovery as a result of management measures implemented under North Carolina, South Atlantic Fishery Management Council or Atlantic States Marine Fisheries Commission Fishery Management Plans. The proposed reduction in mesh size could result in increased bycatch in these species and delay recovery of the stocks.

The NCDMF is opposed to the language in the Proposed Rule that will require the inshore 300 feet of a stop net to be constructed of four inch or less stretched mesh webbing. We recommend that the maximum mesh size not apply to stop nets. We also recommend that observer coverage be increased in this fishery to provide data as to whether or not bottlenose dolphin strandings in the vicinity of stop nets are related to this or other fisheries.

Proposed Rule: Gear-area Measures – *Gear marking requirements for all regulated and exempted waters,* p. 65132 and Table 3 Gear Marking Requirements for All Fisheries:

The NCDMF does not support the gear marking requirements in the Proposed Rule or the January 13-14, 2005 TRT consensus recommendations on gear marking. Marking requirements for gear in exempted waters were not discussed by the TRT at any of the meetings and were not consensus recommendations from the May 2002 or April 2003 meetings.

The proposed gear marking requirements will conflict with North Carolina's marking requirements that have effectively identified gill net gear and owners since 1987. Furthermore, it would be costly for North Carolina fishermen to replace currently required gear markings with the proposed equipment, and the change in markings would be confusing to fishermen and the boating public. The proposed requirement for identification tags for gill nets is problematic in fisheries that use gill nets that are fished from net reels. Tags are likely to become entangled in the webbing and the tags and/or the nets damaged when the gear is being fished from net reels. It is recommended that the identification of gill net mesh size on floats with permanent marker or by engraving be included as an alternative to the proposed identification tag requirement.

The proposal to require one end of gill nets to be marked with flags that extend at least three feet above the surface of the water is unacceptable for some North Carolina exempted waters fisheries. Inside waters fisheries for flounder, spotted sea trout and red drum are often prosecuted in water that is less than thee feet deep. In order for a flag to extend three feet above the surface of the water, a staff three feet in length will be required below the surface of the water; such a flag would not stand up in water three feet deep. The proposed requirement for marker flags to extend three feet above the surface of the water is not applicable to shallow water and should not be a marking requirement in exempted waters.

North Carolina Fisheries Rules for Costal Waters require that commercial fishing gear, whether used by commercial or recreational fishermen, be marked by buoys made of solid buoyant material. Commercial gill nets are required to be marked at each end with two yellow buoys, not less than five inches in length and recreational gill nets are required to meet the same requirements with an additional hot pink buoy on each end of the net. Owner identification information is required on the buoys. North Carolina has proven and effective systems for marking and identifying gear. It is recommended that North Carolina gear marking and identification requirements be allowed as an alternative to the Proposed Rule for North Carolina regulated and exempted waters.

Thank you for the opportunity to comment on the Bottlenose Dolphin Take Reduction Plan Proposed Rules. Please feel free to contact me or Fentress Munden at PO Box 769, Morehead City, NC 28557 or by phone at 252-726-7021 if you need additional information.

Sincerely,

Preston P. Pate, Jr., Director
North Carolina Division of Marine Fisheries

PPP/FHM:bl

cc Jimmy Johnson
Louis Daniel

Supplement 2. North Carolina Marine Fisheries Commission comments on the proposed rules for the Taking of Marine Mammals Incidental to Commercial Fishing Operations; Bottlenose Dolphin Take Reduction Plan

David Bernhart, Chief
Protected Resources Division
National Marine Fisheries Service
9721 Executive Center Drive North
St. Petersburg, FL 33702-2432

Dear Mr. Bernhart:

The North Carolina Marine Fisheries Commission (NCMFC) appreciates the opportunity to comment on the National Marine Fisheries Service (NMFS) proposed rule on the Bottlenose Dolphin Take Reduction Plan (BDTRP) and the Sea Turtle Conservation Restrictions published in the Federal Register on November 10, 2004. The MFC also wants to thank the NMFS, especially Dr. Bill Hogarth, for holding a public hearing in North Carolina on the proposed rule. We are glad the meeting was well attended and hope NMFS will utilize the public comments provided at the meeting when deciding on the wording of the final rule. The NCMFC also commends the NMFS for utilizing a Take Reduction Team (TRT) composed of stakeholders to help develop the proposed rules for bottlenose dolphin management.

The proposed BDTRP rule will have a significant impact on North Carolina gill net and seine fisheries. These fisheries are some of the most active fisheries in North Carolina and impact numerous fishermen. Our gill net fisheries are among the most valuable and important fisheries in the state of North Carolina.

Due to the potential impacts of the proposed rule, the MFC held six public meetings through our advisory committee system to receive input for potential comments. The MFC Finfish, Striped Mullet Fishery Management Plan (FMP), Northeast Regional, Central Regional, Southeast Regional, and Inland Regional committees all spent hours reviewing and discussing the proposed rule. Over 100 people attended these meetings.

The NCMFC strongly opposes the new gill net and seine marking requirements proposed by NMFS. The NCMFC already has rules that adequately identify gill nets and seines, which provide the state of North Carolina and NMFS information needed to identify responsible parties. We have been informed that the TRT did not recommend these measures and that instead, they originated from NMFS. The NCMFC suggests that NMFS consider imposing gear marking in states that do not require such, rather than enacting redundant and unnecessary regulation on North Carolina fishermen who are already required to responsibly mark their gear.

The NCMFC recommends that any monofilament gill net fishery, whose nets are deployed and actively fished in North Carolina's waters, be allowed to continue as it is currently prosecuted. These gill nets are commonly known as run-around, drop gill nets. There are several gill net fisheries in state waters that use less than or equal to 5 inch stretched mesh, where the nets are set and actively worked. One of the most important of these fisheries is the roe mullet (striped mullet) fishery, which uses 5 inches or less

stretched mesh gill net in the near shore area during fall. The net is placed in the water, fishermen stay with the gear, and the net is actively fished. The proposed NMFS rule that would prohibit any monofilament gill net within 100 yards of the beach and would require that one use 4 inch or less stretched mesh would eliminate this fishery. The NCMFC is unaware of any NMFS's data that show bottlenose dolphin interactions with this fishery. The TRT did not discuss a proposal to ban monofilament gill nets within 100 yards of the beach. The NCMFC requests that NMFS reconsider the near shore proposed monofilament gill net restrictions in light of this information.

The NCMFC asks that NMFS also consider allowing historical monofilament gill net fisheries set and left within near shore (100 yard area) that use less than or equal to 5 inch stretched mesh webbing. Several set gill net fisheries, using small monofilament webbing, have existed for years in North Carolina. The fishermen in these fisheries dispatch their gill nets by boat within 100 yards of the beach, leave them, and come back to fish them later that day or the next morning. These fisheries are especially prevalent south of Cape Lookout, North Carolina and target spot and kingfish, among other species.

The NCMFC asks the NMFS to reconsider the application of the beach gear restrictions to North Carolina's stop net fishery for striped mullet. The original TRT recommendation was intended to prohibit the use of monofilament webbing in the North Carolina Atlantic Ocean striped bass beach seine fishery, not the seine gear used in this fishery. The NCMFC also notes that the Environmental Assessment for the proposed rule is inadequate in that it does not mention impacts on this fishery. The NMFS proposed rule would prohibit seine gear within 100 yards of the beach unless it is 4 inches or less multi-filament nylon. Stop nets are composed of multi-filament material that extends approximately 400 yards from the shore. Small mesh (less than or equal to 5 inches) seines are used within the stop net to encircle mullet. Since 1994, North Carolina has required that stop nets be composed of 6-8 inch stretched mesh and only allowed four sets. The state of North Carolina required that mesh size to reduce bycatch, such as red drum and sharks and to minimize conflict between mullet fishermen, recreational fishermen, and pier owners. The large mesh size alleviated concerns from North Carolina recreational fishermen and pier owners that the stop nets were preventing near shore migration of some species, such as spot. The use of stop nets along Bogue Banks, the only place where this fishery now occurs, historically caused much conflict among user groups. The requirement of using 6-8 inch mesh in the stop net has helped tremendously in alleviating this conflict. The NMFS proposed rule has a high likelihood of increasing bycatch of actively managed and important species, will also increase user conflicts in North Carolina, or will eliminate one of North Carolina's oldest fisheries.

The NCMFC has concerns about the proposed amendment to the existing mid-Atlantic large mesh seasonal closures to reduce the incidental take of sea turtles in North Carolina's waters. Specifically we are concerned about the extension of the seasonally closed area from Oregon Inlet to Currituck Beach Light into state waters. Most of the Exclusive Economic Zone (EEZ) off North Carolina is currently closed to large mesh gill nets from March 16 – January 14. Current MFC rules prevent large mesh gill net use in state waters from April 15 – December 15. The proposed NMFS rules concerning bottlenose dolphin mirror what the NCMFC has already in effect. The NCMFC recommends that NMFS utilize the same dates (April 15 – December 15) for the sea turtle closures as those being recommended to protect bottlenose dolphin. Synchronizing the dates would allow North Carolina fishermen to continue to use large

mesh webbing to capture monkfish in state waters. That fishery is very limited in seasonality and NMFS intensively manages the EEZ fishery through limited entry permits. Fishermen said at our committee meetings that NMFS also requires extensive observer coverage in the fishery for state waters.

The NCMFC does support the following NMFS's proposed rules which were a result of consensus-building by the TRT: 1) VA/NC border to Cape Lookout, NC – a) from May 1 – October 31 no person may fish with small mesh gill net using lengths of nets longer than 1,000 feet and b) no fishing with large mesh gill net from April 15 – December 15; 2) Cape Lookout to NC/SC line – no fishing with large mesh gill net from April 15 – December 15; 3) VA/NC border to Cape Lookout, NC – a) from November 1 – April 30 no fishing at night with medium mesh gill net (with a sunset clause) and b) from December 16 – April 14 no fishing at night with large mesh gill nets unless the nets use tie-down; 4) Cape Lookout, NC to NC/SC line – a) from November 1 – April 30 no fishing at night with medium mesh gill nets (with sunset clause) and b) from November 1 – April 30 no fishing at night with large mesh gill nets.

The NCMFC is also on record in North Carolina of supporting a seine fishery with multi-filament webbing that is < 7 inches stretched mesh in the Atlantic Ocean striped bass seine fishery north of Cape Lookout, NC. This fishery was specifically addressed by the TRT. This fishery is very seasonal and intensively managed by North Carolina, occurring for very limited days between November – December. In 2004 the season lasted only two days.

The NCMFC hopes NMFS utilizes these comments when formulating its final rule. North Carolina's fishermen will be most impacted by NMFS's proposed rule relative to any other user group on the Atlantic coast. As a result of these potential impacts, the NCMFC has a substantial interest in the final rule. As representatives of North Carolina, we sincerely desire to cooperate with NMFS in regards to responsible management of our ocean's resources. We will be glad to meet with NMFS representatives at any time to discuss our concerns.

Sincerely,

James A. Johnson, Jr.
Chairman
North Carolina Marine Fisheries Commission

Cc: Senator Elizabeth Dole
Senator Richard Burr
Representative Walter B. Jones, Jr.
Representative Mike McIntyre
Representative G.J. Butterfield
Bill Hogarth – Assistant Administrator, for Fisheries
NCMFC
Preston Pate – Director, Division of Marine Fisheries
Frank Crawley – NC Attorney General
Jess Hawkins – NCMFC Liaison

11.8 Appendix 8. PROPOSED RULES

Underlined text in the following rules denotes proposed new language. Strike through text denotes proposed deletions to the rule.

03M .0502 MULLET

(a) The Fisheries Director may, by proclamation, impose any or all of the following restrictions on the taking of mullet:

1) Specify season,
2) Specify areas,
3) Specify quantity,
4) Specify means/methods,
5) Specify size.

(b) It is unlawful to possess more than 200 mullet per person per day for recreational purposes.

03M .0101 MUTILATED FINFISH

It is unlawful to possess aboard a vessel or while engaged in fishing from the shore or a pier any species of finfish ~~which~~ that is subject to a size or harvest restriction without having head and tail attached, except for mullet when used for bait. Blueback herring, hickory shad and alewife shall be exempt from this Rule when used for bait provided that not more than two fish per boat or fishing operation may be cut for bait at any one time.

12. ATTACHMENTS

12.1 Attachment 1. Population assessment of the North Carolina striped mullet (*Mugil cephalus*) stock.

Summary

Introduction

A population assessment of the North Carolina striped mullet (*Mugil cephalus*) stock was conducted by means of a statistical catch-at-age-analysis based on the stock synthesis approach by Methot (1990; 2000). This population model is an age- and size-based forward projection analysis, incorporating a wide collection of fishery-dependent and -independent data. Age-specific estimates of population abundance and commercial and recreational fishing mortalities for each half-year period covering a nine-year time series (1994-2002) were produced in the population model for separate male and female populations. Benchmark fishing mortality rates proposed as thresholds for sustainability, were calculated using life history and fishery information unique to the North Carolina striped mullet stock. Observed fishing mortality estimates from the population model were evaluated in relation to the fishing mortality thresholds, to determine if overfishing is occurring on the stock.

Striped mullet inhabiting North Carolina estuarine and inland waters comprise the unit stock in the assessment. The North Carolina striped mullet stock falls under the jurisdiction of the North Carolina Marine Fisheries Commission and the North Carolina Wildlife Resources Commission. The North Carolina Division of Marine Fisheries (DMF) directly manages the stock under these two regulatory commissions. No inter-state management over the Atlantic coastal striped mullet population is in effect.

The North Carolina striped mullet commercial fishery is the largest along the U.S. Atlantic seaboard, averaging 2.18 million pounds from 1994 to 2002. The commercial fishery is predominantly a fall, roe targeting, gill net fishery. Rapid surges in roe value in the late 1980s, followed by rising commercial fishing effort and landings through the mid 1990s caused concern for the North Carolina stock. The stock has been officially recognized as a species of concern by the state of North Carolina since 1999.

Recreational landings in North Carolina are smaller than commercial landings, and are composed of two types of harvest: cast netted juveniles used for hook and line bait, and recreationally gill netted striped mullet. Annual recreational bait harvest in North Carolina consists of approximately 350,000 striped mullet. The DMF estimated that 66,205 striped mullet (equivalent to 64,213 lb) were recreationally harvested by small mesh gill nets in 2002. Recreational gill net landings are harvested by Recreational-Commercial Gear License (RCGL) holders.

Data Sources

Life history data sources utilized in the assessment included two sources of age-growth data, a length-weight relationship, a length-based maturity curve for females, length-based sex-ratio information, and an age-specific natural mortality model. Fishery landings and age compositions from the recreational and commercial sectors were included in the population model. RCGL harvest was included in the commercial fishery

landings, given the similarity in capture gears (i.e. small mesh gill nets). It was necessary to view RCGL landings with commercial landings due to the lack of RCGL size (or age) information. Recreational landings in the assessment, therefore, consisted only of bait harvest. Commercial fishery gill net catch-per-unit-effort (CPUE) and four DMF fishery-independent surveys provided information about year-to-year stock abundance. Of the four DMF fishery-independent surveys, two gill net surveys provided indices of adult CPUE and length compositions, and two seine surveys served as juvenile abundance indices (JAI).

Results

Based on the population model results, the three highest estimates of age 0 recruitment (R_0) have occurred in the most recent five years, peaking in 2002. High yearly levels of R_0 are characteristic for the stock, averaging 61 million new recruits per year. Female spawning stock biomass (SSB) has increased from 1994 to 2002, with peak SSB occurring over the last three years of the assessment.

Fishing mortality (instantaneous rate, *F*) was estimated separately for the recreational and commercial fisheries, notated as F_r and F_c. Fishing mortality was also estimated for each January-June and July-December period, referred to as $F_{c\,Jan}$ and $F_{c\,Jul}$, as examples. Full year fishing mortality is the sum of the seasonal *F* rates within a year, written as $F_{r\,Tot}$ or $F_{c\,Tot}$.

Only minor recreational fishing mortality (F_r) is incurred on juveniles from recreational bait harvest. Recreational fishing mortality occurs almost exclusively on age 0 individuals from July to December. Essentially, the large numbers of striped mullet cast netted by anglers for bait is minimal in relation to the vast numbers of age 0 recruits that are produced each year.

Commercial *F* (F_c) is disproportionately higher on females than males and occurs with greater intensity in July-December than in January-June. On average, 66% of the $F_{c\,Tot}$ on males, and 91% of the $F_{c\,Tot}$ on females occurs in the July-December period. The commercial fishery also targets different age classes between the two seasons, as larger, older fish are sought in July-December. Full 100% selectivity (or full vulnerability) to the fishery occurs at age 2 in January-June, and at ages 3 and 4 for males and females in July-December. These age classes are considered 'fully-recruited' to the fishery. Fishing mortality on fully-recruited age classes is hereby referred to as 'Full' *F*.

Full $F_{c\,Tot}$ on males has been stable from 1994-2002, averaging 0.80. Average commercial *F* on fully recruited females was 1.25. The heaviest exploitation on females and the largest fluctuations in $F_{c\,Tot}$ occurred in the early years (1994-1998) of the nine-year time series. The average full commercial fishing mortality on females over the last four years of the assessment (1999-2002) was $F_{c\,Tot}$ =1.09.

Overfishing Definitions

By definition, overfishing occurs when the fishing mortality rate exceeds the threshold *F* rate and the rate of removal of fish exceeds the ability of the stock to replenish itself (ASMFC 2004). Yield per recruit (YPR) and spawning stock biomass per recruit (SSB/R) modeling, and a replacement analysis of observed stock-recruitment

data were used for defining *F*-based overfishing thresholds for the stock. The following benchmarks and thresholds are given as full year fishing mortality rates on fully-recruited age classes.

F_{max} and $F_{0.1}$ were used as benchmarks to assess overfishing on males. $F_{0.1}$ is considered a conservative proxy for fishing at maximum sustainable yield (MSY) for some species. Overfishing is not occurring on males, considering recent fishing mortality rates (1999-2002 average Full $F_{c\,Tot}$ =0.71) in relation to $F_{0.1}$ =0.58 and F_{max} =1.65. It is likely that male abundance is adequate for overall stock sustainability, considering stable commercial *F* rates, increasing age 0 recruitment, and the generally reduced importance of males to reproduction and sustainability.

The threshold *F* rate for females was based on a level of fishing that conserves 25% of the spawning stock biomass (SSB) compared to a condition where no fishing mortality occurs (*F* =0). This percentage of SSB is known as spawning potential ratio (SPR). This fishing threshold of $F_{25\%}$ =1.25 was considered a proxy for *F* at maximum sustainable yield (F_{msy}) for the stock. Adopting a threshold fishing mortality corresponding to SPR =25% was primarily based on rapid growth to maturity, large annual age 0 recruitment, and greater than 100 years of historical commercial landings similar in magnitude to the current fishery, ostensibly indicating a long-term self-sustaining stock at this level of exploitation. Replacement benchmarks F_{med} =1.37 and F_{low} =1.08 suggest that fishing at $F_{25\%}$ would result in sufficient recruitment to sustain current stock size.

Although the female stock is heavily exploited, overfishing is technically not occurring based on $F_{25\%}$ as the threshold fishing mortality rate. The 1994-2002 average commercial fishing mortality on females is Full $F_{c\,Tot}$ =1.25, with the 2000-2002 average =1.15. Terminal year (2002) Full $F_{c\,Tot}$ =1.11. The distinct pattern of very low commercial fishing mortality in January-June, combined with shifting fishery selectivity towards older fish in July-December, allows females to attain maturity before they face the full brunt of fishing mortality. Terminal stock abundance and age structure is most likely at sustainable levels, given the expanding SSB and high levels of R_0 estimates observed in the population model, and stable commercial *F* rates on females equivalent to 26-27% equilibrium spawning potential ratio of the stock over the most recent three years of the assessment. Although SSB and age structure likely maintain current harvest levels, reproduction comes heavily from younger age classes, requiring cautious management of the stock. A series of poor recruitment events could upset stock sustainability.

Given $F_{25\%}$ as a proxy for F_{msy}, the stock is currently fished near the maximum exploitation level that can maintain sustainability, thus leaving little room for acknowledged uncertainty in data used in the assessment or against unpredictable future events such as recruitment failures. The typical management response to dealing with uncertainty is to adopt more conservative thresholds that are considered precautionary (Haigh and Sinclair 2000). A target of $F_{30\%}$ =0.98 would be a sensible option as a precautionary threshold for the stock.

Introduction

Unit Stock Definition

Striped mullet inhabiting North Carolina estuarine and inland waters comprise the unit stock in this quantitative assessment. Tagging studies in North Carolina indicate a residential adult stock (Wong 2001; Bacheler et al. in review). Only seven (1.8%) of 384 recaptured striped mullet that were dart-tagged (n =14,987) in North Carolina between 1997 and 2001 were recovered out-of-state (Wong 2001). Striped mullet tagging studies in general, reveal a small mark-recapture distance, and a typical southward spawning migration along the south Atlantic Bight (SAB) (Mahmoudi et al. 2001; McDonough 2001; Wong 2001). An observed northward movement pattern during and after its spawning period suggests that adults continue to colonize North Carolina estuarine habitats after its southward spawning migration (Bacheler et al. in review). In conjunction with the southward (and offshore) spawning migration by adults, the northward advection of eggs and larvae via the Gulf Stream likely provides some measure of self-replenishment of the North Carolina stock. However, the influx of eggs and larvae into North Carolina from stocks residing in South Carolina to Florida is uncertain, as is the northward loss of North Carolina-born eggs and larvae into the mid-Atlantic Bight. Although these larval recruitment processes that occur on a coastwide scale would suggest a genetically homogenous striped mullet population in the SAB, the assumption of a distinct North Carolina stock was necessary for this assessment. As a reference, the Gulf States Marine Fisheries Commission considers all striped mullet occurring in the United States Gulf of Mexico as one population because of widespread larval mixing, but also recognizes that state-specific or regional management programs (including assessments) are appropriate because of the limited movement patterns observed by juveniles and adults (Leard et al. 1995).

Management Jurisdiction

The North Carolina striped mullet stock falls under the jurisdiction of the North Carolina Marine Fisheries Commission and the North Carolina Wildlife Resources Commission. The North Carolina Division of Marine Fisheries (DMF) directly manages the stock under these two regulatory commissions. No inter-state jurisdictional management over the Atlantic coastal striped mullet population is in effect.

Objectives

The objectives of this quantitative assessment are to estimate fishing mortality rates and population abundance of the North Carolina striped mullet stock, and to relate those fishing mortality rates to threshold levels that are considered appropriate for a sustainable fishery.

Fisheries

Striped mullet are both commercially and recreationally harvested in North Carolina. Aside from season and area closures pertaining to the stop net-beach seine commercial fishery effective since 1991 (see FMP Description of Commercial Fisheries), there are no specific restrictions on striped mullet in either commercial or recreational fisheries. Rapid surges in roe value in the late 1980s, followed by rising commercial fishing effort and landings through the mid 1990s caused concern for the North Carolina

stock. The stock has been recognized as a species of concern by the state of North Carolina since 1999.

Over the past ten years, North Carolina has averaged the largest, commercial striped mullet landings along the U.S. Atlantic coast. The North Carolina commercial fishery is largely a fall, roe fishery, with 53% of the total yearly landings harvested in the spawning months of October and November. Total commercial landings have shown a slight increase from 1994 to 2002, averaging 2.18 million pounds, with sporadic depressions caused by severe fall hurricanes in 1996 and 1999 (see FMP Description of Commercial Fisheries). Nearly half (48%) of the total landings are composed of spawning females and males graded as red and white roe market categories, not including an unknown further contribution of spawning fish landed from September to March in non-roe market categories. The commercial fishery has become a predominantly gill net fishery, as 92% of the landings from 1994 to 2002 were harvested by gill nets, six percent by seines, and two percent by other gears. Virtually no striped mullet discard was found to occur in the commercial fishery in an DMF investigation (see FMP Bycatch Assessment of Striped Mullet in North Carolina Fisheries).

Two types of recreational striped mullet harvest occur in North Carolina: angler-harvested bait and hook and line landings estimated by the Marine Recreational Fisheries Statistics Survey (MRFSS) of the National Oceanic and Atmospheric Administration (NOAA), and recreational landings captured by commercial gears with a North Carolina recreational-commercial gear license (RCGL) estimated by DMF. The striped mullet MRFSS harvest is assumed to be entirely composed of juveniles used as bait for hook and line fishing. The MRFSS survey began accounting for bait harvest of 'mullets' (including white mullet (*Mugil curema*)) beginning in 2001. On average, 1.23 million mullets were harvested by recreational anglers in 2001-2002. In a 2002-2003 study, DMF concluded that 29% of recreational bait mullet were specifically composed of striped mullet, which equates to approximately 350,000 striped mullet individuals harvested by recreational anglers per year (see FMP Characterization of Bait Mullet Cast Net Fishery). DMF began estimating landings by RCGL holders in 2002. The DMF RCGL survey indicated that 66,205 striped mullet (equivalent to 64,213 lb) were recreationally harvested by small mesh gill nets in 2002.

Data Sources

Life History Information

Age-Growth

Two discrete sources of age-length data were used in the assessment; age-length key data and monthly age 0 length distributions. Age-length keys constructed from DMF age-length sampling on sub-adult to adult size ranges were used for converting fishery lengths to fishery age compositions. Monthly length compositions of age 0 fish were included in the population model to provide growth information for the early stages of the von Bertalanffy (LVB) growth curve.

Age-Length Keys

Age-length key data used to construct the commercial and recreational age compositions were collected from fishery-dependent and -independent sources by DMF

beginning in 1997. Fixed numbers of specimens from 50 mm length classes were targeted on a monthly schedule. Ages were determined from sectioned, polished sagittal otoliths, based on a 1 January birth date. Age-length keys were based on ½ year units (January-June, July-December), with smallest sample sizes occurring in 1997 (Figure 1).

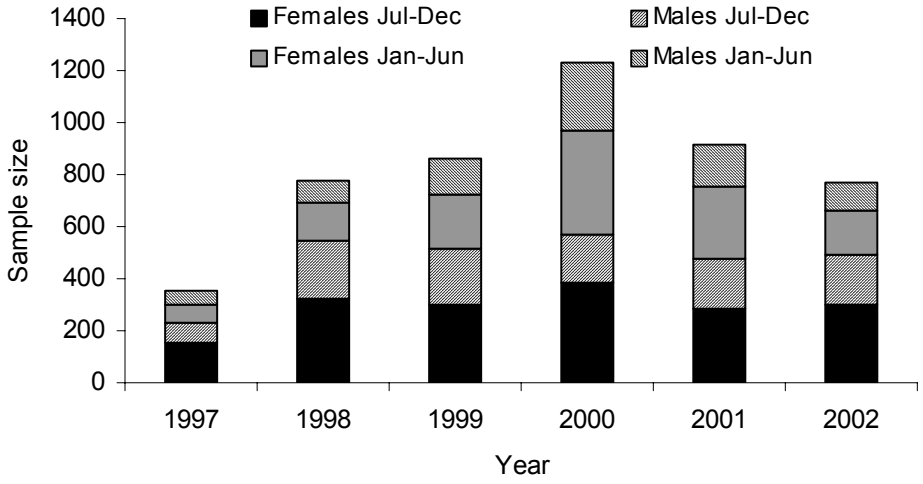

Figure 1. Sample sizes of each 1/2 year, split sex age-length key from 1997-2002.

Von Bertalanffy growth curves from age-length key data (pooled across years) indicated rapid growth (especially for males) and similar lengths-at-ages for males and females up to age 2 (Table 1). Male growth slows in relation to female growth at age 2, as males attain a smaller asymptotic maximum length at a slightly earlier age (Table 1). Oldest observed ages for males and females were seven and 11 years. Sample sizes from age-length keys predominantly consisted of specimen's ≥200 mm FL, so little information was available to describe early stages of growth. The unusual lengths at ages 0.0 and 0.5 for males seen in the age-length key data may be related to the limited sample sizes at small size classes, which fails to constrain the T_0 parameter in the LVB analysis, or possibly to an earlier true birth date than the assumed 1 January convention (although females are unaffected).

Table 1. Von Bertalanffy growth parameters and length-at-age information (fork lengths) from data used to construct age-length keys.

Von Bertalanffy growth parameters	Males (n=1,200)	Females (n=2,480)
L_{inf}	403.0	504
k	0.50	0.43
T_o	-0.38	-0.11

Age	Males	Females
0.0	69	24
0.5	143	117
1.0	200	192
1.5	245	253
2.0	280	302
2.5	307	341
3.0	328	373
3.5	345	398
4.0	357	419
4.5	368	435
5.0	375	449
5.5	382	459
6.0	386	468
6.5	390	475
7.0	393	481
7.5	395	485
8.0	397	489
8.5	399	492
9.0	400	494
9.5	400	496
10.0	401	498
10.5	402	499
11.0	402	500

Age 0 Length Compositions

Early life history growth information from observed age 0 length compositions was used to help estimate new LVB parameters in the population model. Monthly length compositions were provided from an Albemarle Sound seine survey conducted by North Carolina State University (NCSU) (Buckel et al., unpublished data). Striped mullet were collected biweekly from May through October covering a time series of 2002-2003. The 61 x 3 m beach seine (6.4 mm bar mesh wings and 4.8 mm delta mesh bag) was set by boat at 18 fixed stations. Age 0 length compositions by month were pooled across years (Figure 2).

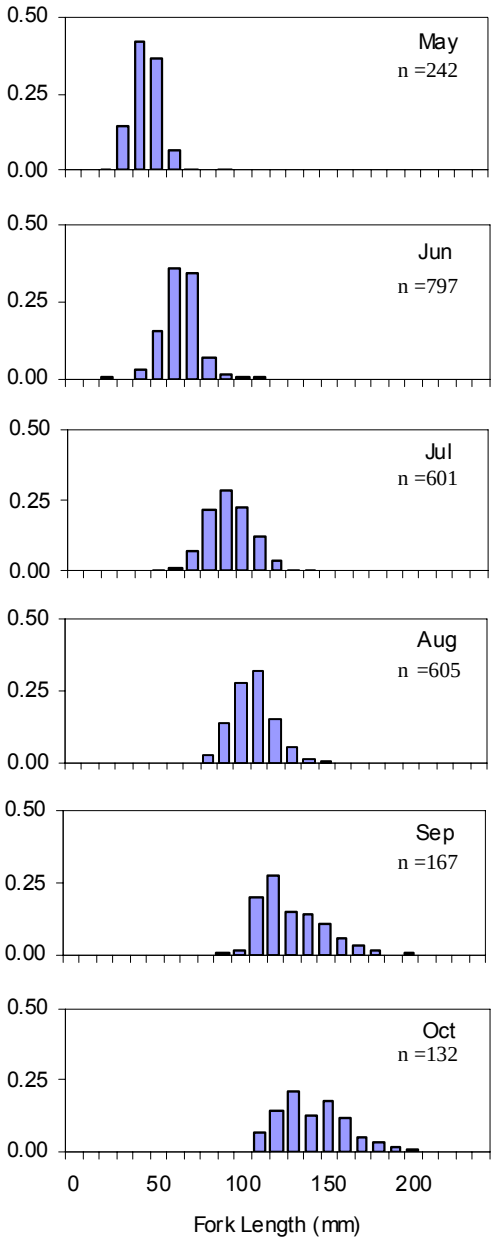

Figure 2. Length proportions by month of striped mullet captured by seine (Buckel et al., unpublished data).

Length-Weight Relationship

A linear, log transformed length-weight relationship derived from DMF age-length key data was used to calculate weights-at-age from von Bertalanffy lengths-at-age in the population model. Given no significant difference in the log transformed length-weight relationships between sexes (ANCOVA, p=0.88), pooled male and female data were used in one length-weight linear equation:

Ln(W) =2.9964 * Ln(L) - 11.127
R^2 =0.9886 n =4,918
W =weight (kg)
L =fork length (mm)

Female Maturity

A length-based female maturity ogive was determined from DMF age-length data using weighted, non-linear least squares estimation (Quinn and Deriso 1999). The maturity ogive was based on the following logistic equation:

% Maturity =1/(1+ $e^{(-k * (L-L50))}$).
k =model parameter
L =fork length (mm)
L_{50} =fork length where 50% maturity

Gonads collected from 1997 to 2002 were macroscopically staged using criteria described in Wenner et al. (1990). Length at 50% female maturity was L_{50} =305 mm FL; *k*=0.0372; n= 2,702 (Figure 3).

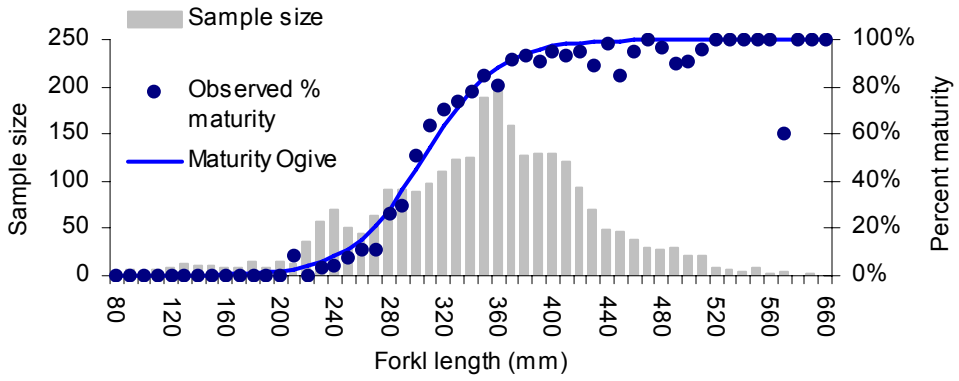

Figure 3. Observed length-at-maturity data, maturity ogive, and sample sizes in each length class (DMF).

Sex Ratio

Length dependent male to female sex ratios were used to split fishery landings by sex in the population model. Ratios were calculated from specimens collected for age-length keys by DMF. Since some data were obtained from fishery-dependent sources, all specimens taken specifically from sex-sorted roe market grades were

removed from the sex ratio analysis.

Female dominated sex ratio begins at 300 mm FL and builds with increasing size (Figure 4) (DMF; McDonough 2001). A substantial proportion of the specimens are still sexually undifferentiated or macroscopically undetermined at 280 mm FL and smaller. Sex ratio was assumed to be 50:50 at size classes less than 300 mm FL for the assessment. Males tend to differentiate earlier than females, which may explain why there are a greater proportion of males than females at smaller size classes in the observed data (Figure 4).

Figure 4. Sex ratio of striped mullet by size class (fork length, mm (DMF)).

Natural Mortality

Various methods for estimating instantaneous natural mortality rates (*M*) were explored using life history information such as maximum age, maximum length, growth rate, mean weight at age, and environmental information such as ambient water temperature (Table 2) (Pauly 1980; Hoenig 1983; Alagaraja 1984). Maximum ages of seven and 11 for males and females observed in DMF data were the oldest documented ages found in the western Atlantic range of the striped mullet.

Table 2. Various instantaneous natural mortality rate (M) estimates for males and females. The model, data description and data inputs for males and females, and M results are listed. M are given as full year instantaneous mortality rates. Mean weights-at-age used in the Lorenzen model are given in grams.

	Data Inputs			Estimated M	
Model	Data Description	Males	Females	Males	Females
Pauly(1980)	Maximum Length (L_{inf} (cm)	40.3	50.4	0.75	0.69
	Growth (K)	0.43	0.41		
	Mean Water Temperature ^{o}C	17.3	17.3		
Hoenig (1983)	Maximum Age	7	11	0.67	0.41
Alagaraja (1984)	Maximum Age	7	11	0.66	0.42
Lorenzen (1996)	Mean Weight at Age 0 (Jan-Jun)	1.1	1.9	2.93	2.51
	Mean Weight at Age 0 (Jul-Dec)	20	35	1.27	1.08
	Mean Weight at Age 1 (Jan-Jun)	68	118	0.89	0.76
	Mean Weight at Age 1 (Jul-Dec)	138	245	0.73	0.62
	Mean Weight at Age 2 (Jan-Jun)	223	399	0.63	0.53
	Mean Weight at Age 2 (Jul-Dec)	312	563	0.57	0.48
	Mean Weight at Age 3 (Jan-Jun)	399	727	0.53	0.45
	Mean Weight at Age 3 (Jul-Dec)	480	883	0.51	0.43
	Mean Weight at Age 4 (Jan-Jun)	554	1025	0.49	0.41
	Mean Weight at Age 4 (Jul-Dec)	618	1152	0.47	0.39
	Mean Weight at Age 5 (Jan-Jun)	674	1263	0.46	0.38
	Mean Weight at Age 5 (Jul-Dec)	721	1359	0.45	0.38
	Mean Weight at Age 6+ (Jan-Jun)	761	1440	0.44	0.37
	Mean Weight at Age 6+ (Jul-Dec)	794	1509	0.44	0.36

Exploitation of juvenile stages (e.g. bait harvest) precipitated the need for a natural mortality model that estimated age specific rates of *M*, rather than assuming a constant natural mortality over all ages. Size dependent natural mortality models lead to more realistic natural mortality rates, chiefly for small sizes of fish, which is especially useful in assessing stocks with exploitation of juvenile stages (Gulland 1987). The Lorenzen (1996) model based on the relationship between body weight and natural mortality was chosen to best estimate age specific rates of *M* for the stock. The Lorenzen (1996) age specific model is described as:

Instantaneous natural mortality *M* (full year) = 3.00 *(mean wt. at age) $^{(-2.88)}$.
(mean wt. at age =grams)

Body weights-at-age were calculated by converting model-estimated von Bertalanffy lengths-at-age to weights-at-age with the length-weight relationship from DMF data.

Other age-specific natural mortality models have been developed specifically for such species as Atlantic menhaden (*Brevoortia tyrannus*), sockeye salmon (*Oncorhynchus nerka*), cod (*Gadus morhua*), and herring (*Clupea harengus*) (De Barros and Toresen 1995; McGurk 1999; ICES 2000; ASMFC 2004). Alternative natural mortality models to the Lorenzen model that could estimate age-specific *M* rates for striped mullet were unavailable.

Fishery-Dependent Data

Three sources of landings from the commercial fishery, recreational fishery, and RCGL holders were available for the assessment covering a time series of 1994-2002. Age compositions from the commercial and recreational fisheries were available from 1997-2002. Commercial gill net catch-per-unit-effort (CPUE) from 1994-2002 served as a fishery-dependent index of adult abundance.

Commercial Fishery Landings

Commercial landings statistics (1994-2002) were provided by the DMF trip ticket program. Commercial landings also included an estimate of undocumented commercial scrap harvest, averaging less than 500 lb per year. Landings from red roe (roe-carrying females) and white roe (spawning males) market grades were treated as 100% females and 100% males, respectively. Landings from non-roe market grades were split by sex by converting landings weight to extrapolated numbers-at-length, using observed length distributions and mean weights of DMF commercially sampled [half year-gear-market grade] categories, and applying length-based sex ratios from DMF age-growth data. Split-sex numbers were returned to split-sex landings using the same commercial mean weights. Size sampling of the commercial catch began in 1997, therefore landings from 1994 to 1996 were split by sex based on the observed, average male to female landings ratio seen from 1997 to 2002. Overall, yearly commercial landings occur predominantly in July-December, and are heavily dominated by female harvest (Figure 5).

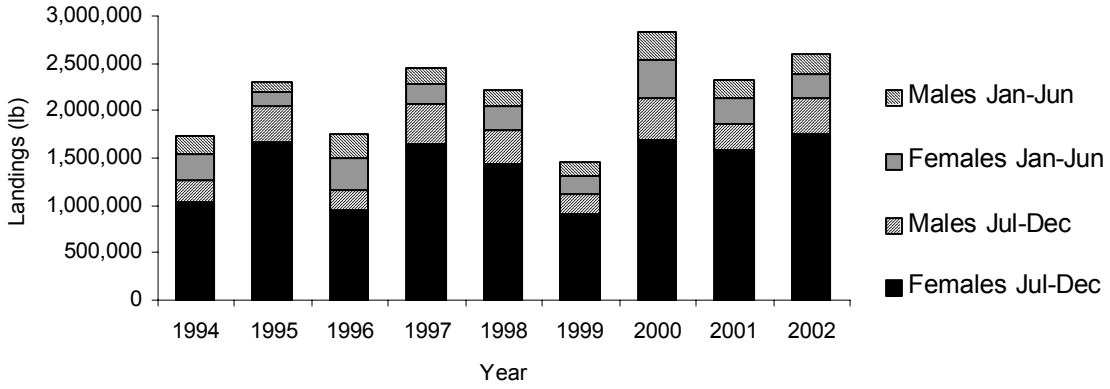

Figure 5. Commercial fishery landings of striped mullet by sex and half year; 1994-2002 (DMF).

Commercial Fishery Age Compositions

Commercial age compositions were included in the assessment covering a time series from 1997-2002. Commercial landings were extrapolated to numbers-at-length using fishery length distributions and mean weights by specific [half year-gear-market grade] categories (DMF unpublished data). Commercial numbers-at-length of non-roe market grades were split by sex using length-based sex ratios from DMF data. Numbers-at-length of red roe and white roe market grades were assigned as 100% females and males. Split-sex, total numbers-at-length were converted to numbers-at-

age using DMF male and female age-length keys based on half-year periods.

January-June Commercial Fishery Age Compositions

Most of the January-June commercial catch is composed of age 2 males and females, with one notable exception in 2001, where age 3 fish formed a significant portion of the catch (Tables 3, 4). More older age classes (> age 2) of females are represented in the harvest than males.

Table 3. January-June commercial striped mullet harvest of males in numbers by age, and sample sizes of age-length keys (ALK), 1997-2002 (NCDMF).

Age	1997	1998	1999	2000	2001	2002
0	0	0	0	0	0	0
1	36,550	18,306	26,518	6,584	3,888	26,620
2	134,082	171,882	127,505	306,553	103,818	189,751
3	12,966	4,715	2,866	8,941	82,939	5,051
4	0	0	2,866	3,576	2,351	8,571
5	0	0	2,866	2,384	0	0
6+	0	0	0	596	0	0
ALK n	49	76	67	141	44	67

Table 4. January-June commercial striped mullet harvest of females in numbers by age and sample sizes of age-length keys (ALK), 1997-202 (NCDMF).

Age	1997	1998	1999	2000	2001	2002
0	0	0	0	0	0	0
1	45,648	13,451	26,146	60	12,517	14
2	190,166	224,381	159,622	391,061	132,468	264,875
3	2,374	31,401	30,174	10,740	129,522	11,229
4	75	5,102	1,434	13,308	7,123	6,904
5	38	646	105	3,129	8,314	2,069
6+	113	0	210	3,923	1,197	830
ALK n	69	146	136	382	161	129

July-December Commercial Fishery Age Compositions

In the July-December fishery, age 1 fish become a significant component of the harvest, ostensibly to increased recruitment to the fishery with increasing size from growth. Male harvest is fairly truncated to ages 1-3, whereas female harvest is composed of a broader mix of ages 1-6 (Tables 5, 6).

Table 5. July-December commercial striped mullet harvest of males in numbers by age and sample sizes of age-length keys (ALK), 1997-2002 (NCDMF).

Age	1997	1998	1999	2000	2001	2002
0	854	10,084	4,864	6,236	671	9,262
1	134,462	89,804	94,538	76,998	70,293	76,516
2	206,455	179,983	41,753	261,920	79,860	183,033
3	17,850	8,332	4,069	0	28,181	8,233
4	0	0	706	0	0	7,577
5	0	0	1,120	0	2,798	0
6+	0	0	0	0	0	0
ALKn	71	171	185	92	95	91

Table 6. July-December commercial striped mullet harvest of females in numbers by age and sample sizes of age-length keys (ALK), 1997-2002 (NCDMF).

Age	1997	1998	1999	2000	2001	2002
0	854	16,732	4,380	2,053	0	9,845
1	254,298	137,236	147,677	114,298	141,778	141,690
2	689,759	683,736	189,193	876,192	180,233	653,575
3	68,900	78,714	136,609	51,758	439,018	93,872
4	26,503	7,743	32,029	49,334	50,200	104,106
5	22,905	1,549	8,354	9,117	31,049	14,281
6+	16,927	3,872	4,177	18,690	2,823	8,568
ALK n	147	263	265	297	194	193

Overall, two year olds form most of the male harvest, with very few males greater than age 4 found in the fishery at any time of the year. The age structure of the female harvest is also mostly composed of age 2 fish (except in 2001), but older age classes are much more common than in the male harvest, especially in the July-December fishery (Tables 5,7). A strong 1998 cohort appears to pass through the fishery based on stronger-than-usual age 1, 2, 3, and 4 age-classes successively through 1999 to 2002.

Commercial Fishery CPUE

Three commercial gill net indices calculated from single-gear runaround trips, set net trips, and combined (runaround +set net) gill net trips were examined as a suitable fishery-dependent index for the assessment. Together, landings from runaround and set net gears account for >90% of the total commercial harvest and capture the same size compositions of fish. Limiting the analyses to trips with only one commercial gear listed on each trip ticket was intended to eliminate any ambiguity in capture gears from multiple gear trips. Furthermore, to address a perceived problem of some commercial fish house dealers confusing runaround and set net gears on trip tickets, CPUE analyses were limited to a subset of dealers (n =27) that were considered to be accurate in reporting gill net types on trip tickets (landings from these dealers made up 23% and 48% of the set net and runaround total). No temporal trends in mesh sizes or net lengths over the time series were observed in DMF fish house sampling data.

The set net CPUE was selected as the most appropriate fishery index of stock abundance for the assessment (Figure 6). Runaround CPUE can be more heavily

affected by schooling artifacts and severe fall hurricanes, since most of the runaround effort occurs during the spawning period. Nevertheless, both runaround and set net CPUE indices indicate upward trends in stock abundance over the 1994-2002 time series (Figure 7). Potential changes in the gill net fishery towards runaround fishing may have occurred in the early period of the time series from 1994-1997 (Figure 8), which could skew the combined gill net CPUE given the greater efficiency in runaround fishing. Otherwise, number of set net and runaround trips trend similarly from 1997-2002 (Figure 8).

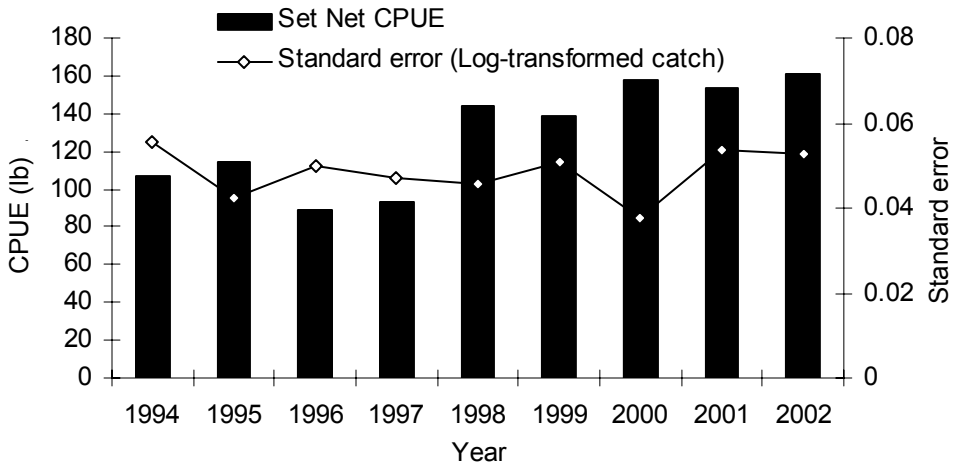

Figure 6. Annual commercial fishery set net CPUE and standard error of the log transformed catch (DMF).

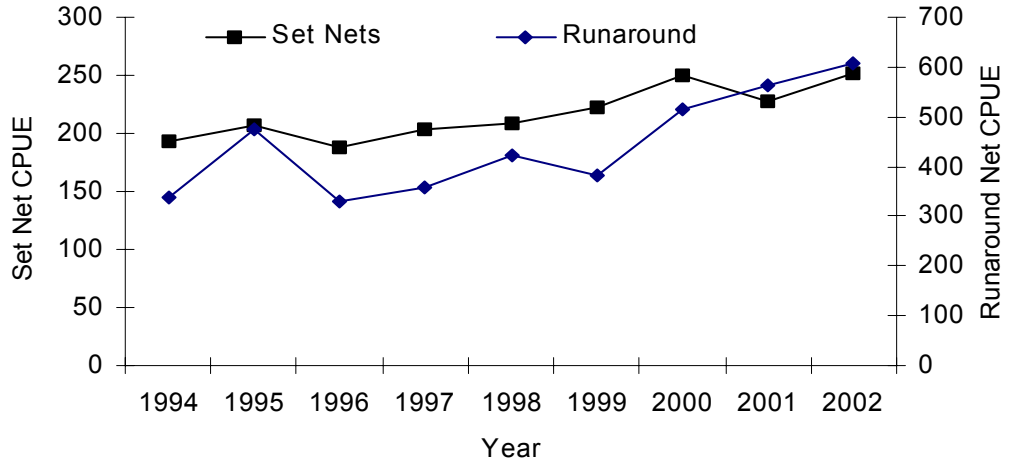

Figure 7. Catch-per-unit-effort indices from commercial set nets and runaround gill nets (DMF).

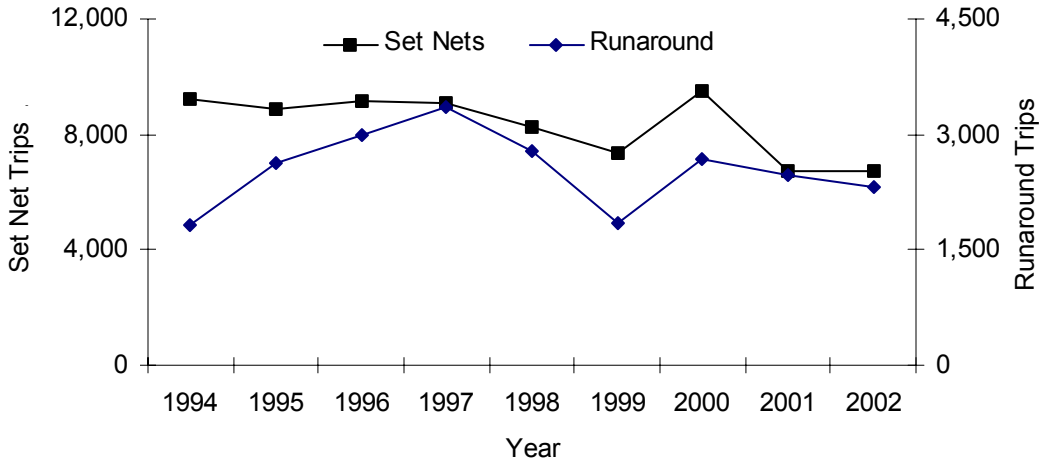

Figure 8. Yearly number of single-gear set net and runaround gill net trips (DMF).

Recreational-Commercial Gear License (RCGL) harvest

66,205 (64,213 lb) striped mullet were recreationally harvested by small mesh gill nets in 2002. Length information was not available from the RCGL survey. With no information about past effort or landings, the 2002 RCGL landings total was assumed constant over the complete time series of the population model. The RCGL landings were added to the commercial landings in the population model, given the gear similarities between the fisheries (92% of commercial landings are harvested from primarily small mesh gill nets).

Recreational Bait Harvest and Age Structure

Estimates of MRFSS landings (numbers) from 1994-2002 and age compositions from 1997-2002 were fit in the population model. Limited years of estimates and lack of species identification in MRFSS sampling necessitated processing of the recreational data before inclusion in the population model. MRFSS essentially began accounting for recreationally harvested bait mullets in North Carolina in 2001. MRFSS, however, does not distinguish between striped and white mullet in their survey. DMF conducted a fishery-independent cast net survey (2002-2003) to determine the mullet species composition in recreational bait harvest to address this data shortcoming. DMF data identified 29% of the cast-netted mullets as striped mullet, over a range of typical recreational fishing areas and months covered by MRFSS (see: FMP Characterization of the Bait Mullet Cast Net Fishery). This proportion was used to define the striped mullet component from the MRFSS combined-mullet harvest estimate. The average striped mullet harvest estimate (353,456 individuals) from 2001-2002 was used as a constant value from 1994 to 2000 in the population model (Figure 9). The modified MRFSS landings were split by sex by extrapolating length compositions from the DMF cast net survey and applying length-based sex ratios from DMF age-growth data.

Sex-specific age compositions of the MRFSS landings were based on extrapolated length compositions from the DMF cast net survey. Length compositions were converted to age compositions with half year, sex-specific, age-length keys from 1997 to 2002. One year olds make up most of the very limited January-June harvest,

whereas age 0 fish comprise the bulk of the principle July-December harvest (Tables 7, 8, 9, 10).

Table 7. January-June recreational fishery striped mullet harvest of males in numbers by age, and sample sizes of age-length keys (ALK), 1997-2002 (NCDMF).

Age	1997	1998	1999	2000	2001	2002
0	3,730	3,730	3,730	3,730	6,585	3,308
1	11,917	12,014	12,220	11,637	8,139	10,342
2	1,048	962	728	1,339	812	1,168
3	14	2	28	0	288	0
4	0	0	1	1	1	1
5	0	0	1	1	0	0
6+	0	0	0	0	0	0
ALK n	49	76	67	141	44	67

Table 8. January-June recreational fishery striped mullet harvest of females in numbers by age, and sample sizes of age-length keys (ALK), 1997-2002 (NCDMF).

Age	1997	1998	1999	2000	2001	2002
0	3,730	3,730	3,730	3,730	4,856	3,308
1	12,515	11,935	12,231	11,670	9,889	10,412
2	483	1,033	695	1,314	898	1,091
3	11	27	82	11	196	11
4	0	14	0	13	5	8
5	0	0	0	0	3	12
6+	0	0	0	0	0	4
ALK n	69	146	136	382	161	129

Table 9. July-December recreational fishery striped mullet harvest of males in numbers by age, and sample sizes of age-length keys (ALK), 1997-2002 (NCDMF).

Age	1997	1998	1999	2000	2001	2002
0	144,209	148,516	147,561	143,320	98,542	196,444
1	11,622	8,612	11,329	10,970	12,132	9,792
2	3,780	2,722	341	5,553	1,798	3,645
3	239	0	197	0	0	93
4	0	0	0	0	0	26
5	0	0	423	7	0	0
6+	0	0	0	0	0	0
ALK n	71	171	185	92	95	91

Table 10. July-December recreational fishery striped mullet harvest of females in numbers by age, and sample sizes of age-length keys (ALK), 1997-2002 (NCDMF).

Age	1997	1998	1999	2000	2001	2002
0	142,494	149,914	147,543	146,787	102,182	197,876
1	15,660	7,577	11,703	8,095	9,124	7,179
2	1,985	2,634	729	5,231	1,203	5,208
3	0	14	164	0	100	58
4	0	0	0	26	67	58
5	0	0	0	0	0	0
6+	0	0	0	0	0	0
ALK n	147	263	265	297	194	193

Fishery-Independent Data

Four indices of striped mullet abundance were generated from DMF surveys, including two juvenile abundance indices (JAI) and two adult gill net indices. Annual variability in survey data was included in the assessment model as standard error of the log transformed catch.

Juvenile Abundance Indices

Juvenile abundance indices from two DMF 60 ft. (18.3 m) seine surveys (6.4 mm bar mesh wings and 4.8 mm delta mesh bag) were used to constrain the age 0 recruitment (R_0) estimates in the assessment model. Length cut-offs by month were implemented to restrict the JAI analyses to age 0 fish (Table 12). Cut-offs were based on minimum size ranges of age 1 striped mullet in age-length key data and on published seasonal growth patterns of young-of-the-year stages in North Carolina (Andersen 1958; DMF). These upper size limits were rarely, if ever met.

Table 11. Length cut-offs for age 0 fish used to calculate JAIs.

	Month						
	May	June	July	August	September	October	November
Fork Length (mm)	101	130	190	205	205	209	225

Alosid Seine Survey

The DMF Alosid seine survey was designed to monitor year-class strength of striped bass (*Morone saxilitis*) and Alosid species in the Albemarle Sound. The survey also serves as an appropriate JAI for striped mullet, due to the shared utilization of low salinity habitats by young-of-the-year (YOY) striped mullet. The JAI was based on months June-October from 1995-2001. The 2002 CPUE was considered potentially spurious based on high catch rates due to abnormally elevated salinity conditions, and was not included in the assessment. Future monitoring should provide a clearer indication of 2002 cohort strength. Catch-per-unit-effort (# fish /tow) fluctuated without trend, with elevated numbers in 1998 and 2000, followed by a very large increase in 2002 (Figure 10).

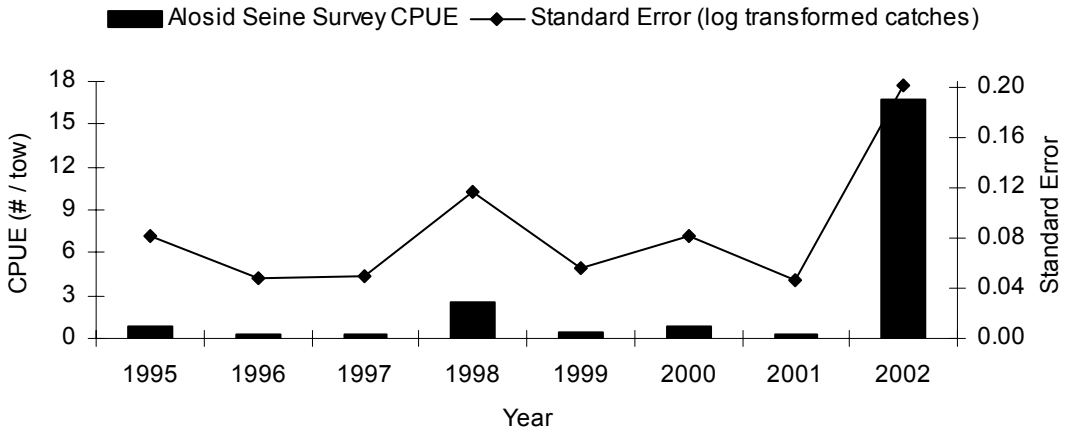

Figure 10. Alosid seine survey CPUE and standard error of the log transformed catches (DMF data).

Juvenile Red Drum Seine Survey JAI

The DMF juvenile red drum seine survey is designed to monitor yearly abundance of age 0 red drum (*Sciaenops ocellatus*) in estuarine areas throughout the state from Croatan Sound to Stump Sound. The yearly JAI covered months September-November from 1994-2002 in the assessment. Annual striped mullet CPUE fluctuated, with elevated YOY numbers in 1998, 2000, and 2002 (Figure 11).

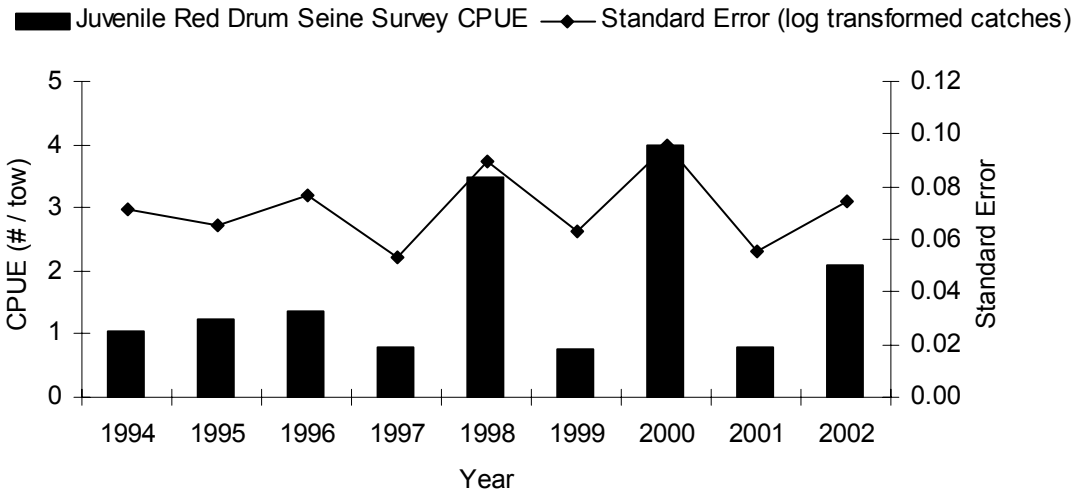

Figure 11. Juvenile red drum seine survey CPUE and standard error of the log transformed catch (DMF data).

Albemarle Sound Multi-Mesh Gill Net Survey

The Albemarle Sound multi-mesh gill net survey is designed to monitor monthly abundances of a wide size range of finfish in shallow and deep waters of the Albemarle Sound. Yearly striped mullet CPUE (# fish /set) and length compositions from the survey were used for the assessment from 1994 to 2002. Monthly random sampling

occurred in shallow and deep strata from January-May and November-December. Nets were composed of multiple 40 yd. (12.2m) panels of mesh sizes spanning 2.5 to 7.0 in. stretch mesh. A slight increasing trend in annual CPUE is observed (Figure 12). Length compositions are fairly uniform in distribution among years, except for the bi-modal distribution observed in 1995 (Table 12).

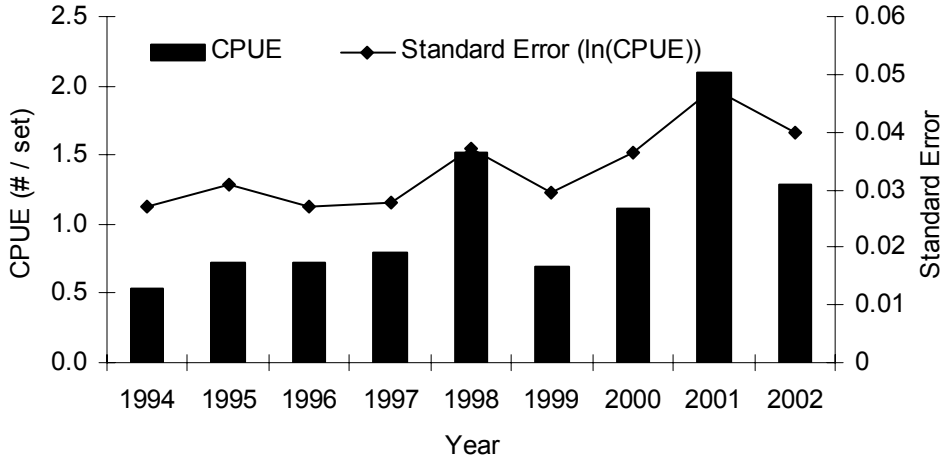

Figure 12. Albemarle Sound multi-mesh gill net survey CPUE and standard error of the log-transformed catch.

Table 12. Annual length compositions of the Albemarle Sound Multi-Mesh Gill Net Survey (NCDMF).

Length Class	1994	1995	1996	1997	1998	1999	2000	2001	2002
<120	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
120	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
140	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
160	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
180	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00
200	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
220	0.01	0.05	0.03	0.01	0.00	0.03	0.01	0.01	0.02
240	0.05	0.20	0.03	0.01	0.03	0.03	0.05	0.03	0.07
260	0.02	0.10	0.03	0.06	0.06	0.06	0.13	0.06	0.13
280	0.03	0.02	0.12	0.28	0.20	0.16	0.22	0.15	0.16
300	0.07	0.02	0.19	0.20	0.32	0.30	0.22	0.17	0.22
320	0.25	0.09	0.19	0.18	0.21	0.22	0.17	0.32	0.16
340	0.28	0.19	0.18	0.13	0.11	0.08	0.08	0.18	0.10
360	0.15	0.18	0.09	0.07	0.03	0.05	0.02	0.04	0.08
380	0.08	0.06	0.06	0.03	0.02	0.02	0.04	0.02	0.03
400	0.04	0.02	0.04	0.00	0.00	0.04	0.02	0.00	0.01
420	0.01	0.04	0.01	0.01	0.00	0.01	0.02	0.00	0.00
440	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.00	0.00
460	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
480	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
500+	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Sample Size	178	255	249	287	544	261	403	730	443

Striped Mullet Trammel Net Survey

The trammel net survey was designed to monitor monthly striped mullet abundance in shallow estuarine areas of Core Sound, Adams Creek, and Newport River. Available data covers a time series from 1999-2002. The 182 m trammel net consisted of a 2.5 in. stretch-mesh inner panel and a 14 in. stretch-mesh outer panel. CPUE (# fish /set) was based on catches from April to September. CPUE was highest in 2000 (Figure 13), with little variation in length compositions between years (Table 13).

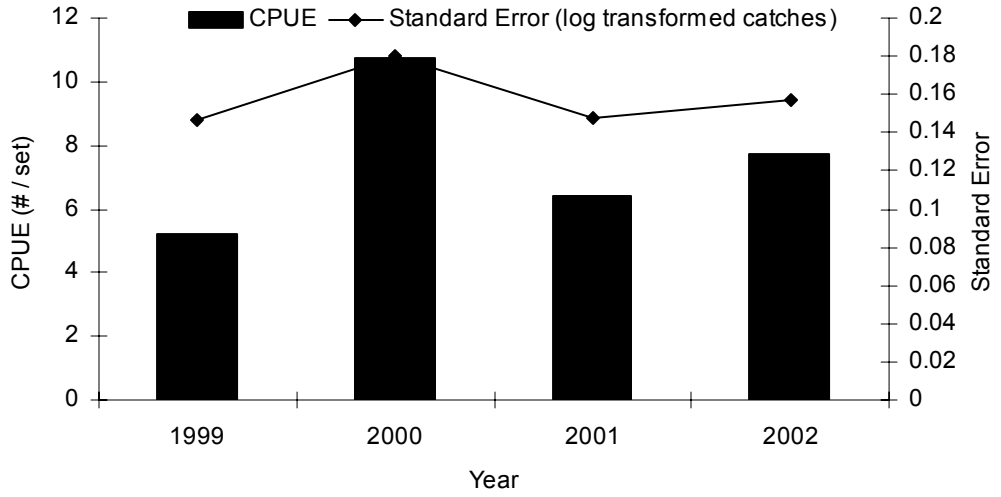

Figure 13. Annual trammel net CPUE and standard error of the log transformed catch (DMF).

Table 13. Annual length compositions of the striped mullet Trammel Net Survey (DMF)

	Length class													
Year	160	180	200	220	240	260	280	300	320	340	360	380	400	Sample size
1999	0.00	0.00	0.03	0.34	0.41	0.16	0.03	0.01	0.01	0.00	0.00	0.00	0.00	311
2000	0.00	0.00	0.01	0.22	0.53	0.20	0.02	0.00	0.00	0.00	0.00	0.00	0.00	644
2001	0.00	0.00	0.06	0.42	0.39	0.08	0.03	0.01	0.01	0.00	0.00	0.00	0.00	383
2002	0.00	0.00	0.02	0.26	0.50	0.16	0.04	0.01	0.00	0.00	0.00	0.00	0.00	463

Assessment Model

Catch-at-age Analysis

A statistical catch-at-age analysis based on the stock synthesis approach from Methot (1990, 2000) was the population model used to assess the status of the North Carolina stock. Stock synthesis consists of an age- and length-based forward projection population simulation, an observation model designed to derive expected values for various fishery and survey data, and a statistical optimization model that bridges observed and predicted values. An underlying philosophy of synthesis is the incorporation of variability in underlying data sources, rather than requiring the data to be highly preprocessed before analysis (Methot 2000).

The stock synthesis approach was favorable given the short time series of age-length data (1997-2002), but an expanded time series of length and abundance data (1994-2002). This approach enabled the population simulation to span 1994-2002. The population structure was divided into two yearly time periods, January-June and July-December, given the seasonally disparate size structures in the commercial fishery (due to fast growth and a market shift towards larger roe fish in the fall). Furthermore, separate male and female populations were assessed based on differing sex-specific

growth, longevity, and harvest characteristics.

Technical Description of the Model Structure

The sex- and age-specific population model used a half-year time step and covered nine years from 1994-2002. The model tracked ages 0 through 6, with the last age category being a pooled group for fish age 6 and older. Model parameters were: (1) historical fishing mortality rate, used to generate the starting number-at-age vector in 1994; (2) nine annual recruitment values; (3) 36 fishing mortality rates for the commercial fishery by half-year and sex; (4) 36 fishing mortality rates for the recreational fishery by half-year and sex; (5) the 16 parameters needed to generate a logistic selectivity pattern by half-year and sex for the commercial and recreational fisheries; (6) the 12 parameters needed to generate double-logistic selectivity patterns (Methot 1990; Quinn and Deriso 1999) for each of the two adult surveys providing length composition data and the age 0 monthly growth survey ; (7) four parameters representing male and female LVB growth parameters k and t_0; and (8) two parameters representing a linear function of the variance in length around the monthly predicted mean for age 0 fish. Fixed values included length-weight parameters, and sex-specific estimates of maximum size (L_{inf}) and variance in length-at-age from LVB growth curves from external age-length key data. The natural mortality rate was an age-specific function of body weight, which was calculated from length-at-age values from the model-derived LVB growth curve and an external length-weight relationship.

Following Fournier and Archibald (1982), Kimura (1990) and Methot (1990), we obtained parameter estimates using multinomial maximum likelihood methods by minimizing the negative log likelihood:

$$-\sum_{ijk} n_{ij}\, p_{ijk}\, \ln\left(\hat{p}_{ijk}\right) + \sum_{i} \frac{\left(\ln\left(C_{ij}\right) - \ln\left(\hat{C}_{ij}\right)\right)^2}{2\sigma^2} + \text{constant}$$

where the first term represents the contribution from size and age distributions (assuming a multinomial error structure) and the second term is the contribution due to various measures of abundance (e.g. fishery landings, juvenile abundance indices, total CPUE) that are examined independently of size or age composition (Methot 1990). For the first term, n_{ij} =sample size for fishery or survey i in year j, p_{ijk} =observed proportion in the age or size distribution from fishery or survey i, year j, age or size class k, and $\hat{p}_{ijk}$ =predicted proportion in the age or size distribution from fishery or survey i, year j, age or size class k. Sample sizes were capped at n =400 (Fournier and Archibald 1982), which prevented excessive weighting of, yet still maintained the overall variability in age or size contributions. For the second term, C_{ij} = observed catch from fishery or survey i in year j, $\hat{C}_{ij}$ = predicted catch from fishery or survey i in year j σ^2 = measured or assumed variance of ln(C_{ij}) (assumed constant over years). To insure a good fit to total commercial landings (in weight) and recreational landings (in numbers), an assumed value of 0.01 was used for σ^2. Data sources fit in the population model are summarized in Table 14.

Table 14. Data sources fit in the catch-at-age analysis population model. 1indicates that split sex data are used. 2The NCSU seine survey includes length data from 2002-2003. (+) indicates that data are fixed at recent values.

Fishery-Dependent	1994	1995	1996	1997	1998	1999	2000	2001	2002
Commercial Fishery Landings[1]	*	*	*	*	*	*	*	*	*
Recreational Fishery Landings[1]	+	+	+	+	+	+	+	*	*
RCGL landings[1]	+	+	+	+	+	+	+	+	*
Commercial Gill Net Fishery CPUE	*	*	*	*	*	*	*	*	*
Commercial Age Compositions[1]				*	*	*	*	*	*
Recreational Age Compositions[1]				+	+	+	+	+	*
Fishery-Independent									
Alosid Seine Survey JAI		*	*	*	*	*	*	*	
Juvenile Red Drum Seine Survey JAI	*	*	*	*	*	*	*	*	*
Albemarle S. Gill Net Survey CPUE	*	*	*	*	*	*	*	*	*
Striped Mullet Trammel Net CPUE						*	*	*	*
Albemarle S. Gill Net Survey CPUE	*	*	*	*	*	*	*	*	*
Length Compositions									
Striped Mullet Trammel Net Survey						*	*	*	*
Length Compositions									
NCSU Albemarle S. Seine Survey									*
Length Compositions[2]									

Population Model Results

Von Bertalanffy Growth Curves

Distinct, sexually dimorphic growth is evident, with considerable size divergence favoring females beginning at age 1 (Table 15). The adjusted T_0 parameters (given the YOY growth data) yielded more realistic sizes at birth (age 0.0) (Table 15). Females attain a larger maximum size, consistent with the fixed L_{inf} parameters from the age-length key data.

Table 15. Model-estimated von Bertalanffy growth parameters and length-at-age information (fork lengths, mm).

	Males	Females
L_{inf}	403	504
K	0.43	0.41
T_o	-0.01	-0.01

Age	Males	Females
0.0	1.7	2.0
0.5	79	94
1.0	141	169
1.5	191	231
2.0	232	281
2.5	265	322
3.0	291	355
3.5	313	383
4.0	330	405
4.5	344	423
5.0	355	438
5.5	365	450
6.0	372	460
6.5	378	468
7.0	383	475
7.5	387	480
8.0	390	485
8.5	393	488
9.0	395	491
9.5	396	493
10.0	398	495
10.5	399	497
11.0	400	498

Commercial Fishery Selectivity

The commercial fishery displays different selectivity patterns for the first half versus the second half of the year, as larger, older fish are targeted as the year progresses. During the January-June period of the fishery, age 2 males and females are fully recruited to the fishery, with very low selectivity exhibited on younger age classes (Table 16). In the second half of the year when most of the harvest occurs, full recruitment to the fishery occurs at age 3 for males and age 4 for females, although age 2 males and age 3 females are essentially fully recruited [98% (Table 16)]. Age 1 males and age 2 females are partially recruited (33% and 65%) to the commercial fishery during this July-December period (Table 16).

Recreational Fishery Selectivity

Similar selectivity curves are exhibited on males and females. From January to June, age 1 fish are fully recruited to the recreational bait fishery, yet very little harvest occurs at this time of the year. Full selectivity occurs on age 0 fish during the peak (July-December period) of the recreational harvest (Table 17).

Table 16. Commercial fishery selectivity rates for males and females for each half year period. 1.00 =full selectivity (or fully recruited to the fishery).

	Males		Females	
Age	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec
0	0.00	0.00	0.00	0.00
1	0.05	0.33	0.03	0.07
2	1.00	0.98	1.00	0.66
3	1.00	1.00	1.00	0.98
4	1.00	1.00	1.00	1.00
5	1.00	1.00	1.00	1.00
6+	1.00	1.00	1.00	1.00

Table 17. Recreational fishery selectivity rates for males and females for each half year period. 1.00 =full selectivity (or fully recruited to the fishery).

	Males		Females	
Age	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec
0	0.09	1.00	0.12	1.00
1	1.00	0.32	1.00	0.23
2	1.00	0.07	1.00	0.03
3	1.00	0.01	1.00	0.00
4	1.00	0.00	1.00	0.00
5	1.00	0.00	1.00	0.00
6+	1.00	0.00	1.00	0.00

Fishery-Independent Survey Selectivities

The NCSU Albemarle Sound seine survey used in estimating von Bertalanffy parameters was selective towards 20 mm to 300 mm FL fish (Figure 14). The two fishery-independent DMF adult surveys selected for different size ranges of striped mullet. The trammel net was selective towards smaller, 200-260 mm FL size classes, whereas the multi-mesh gill net survey was effective at capturing a larger size range of fish (Figure 14).

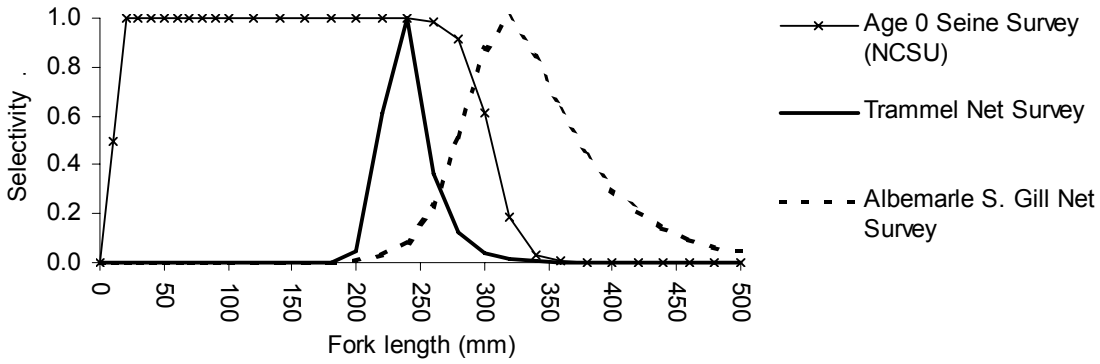

Figure 14. Selectivity curves of fishery-independent surveys. 1.0 = full selectivity to the survey gear.

Commercial Fishing Mortality

Commercial fishing mortality rates (F_c) (incurred from commercial and RCGL harvest) varied between males and females and between half-year time periods. Much higher fishing mortality occurred during the second half of the year for both sexes. Fishing mortality on females was substantially greater than on males during July-December. The sum of the F_c rates from the January-June ($F_{c\,Jan}$) and the July-December ($F_{c\,Jul}$) periods equals the total, full year fishing mortality ($F_{c\,Jan} + F_{c\,Jul} = F_{c\,Tot}$) for each sex.

Commercial Fishing Mortality on Males

$F_{c\,Tot}$ on fully recruited males (*i.e.* Full $F_{c\,Tot}$) declined marginally over the population model time frame averaging $F_{c\,Tot}$ =0.80, with terminal year (2002) $F_{c\,Tot}$ =0.62 (Figure 15). On average, Full $F_{c\,Tot}$ was split 34:66 between the first and second halves of the year, averaging Full $F_{c\,Jan}$ =0.28, while Full $F_{c\,Jul}$ =0.53. Age specific F_c rates for each time period are presented in Tables 18, 19.

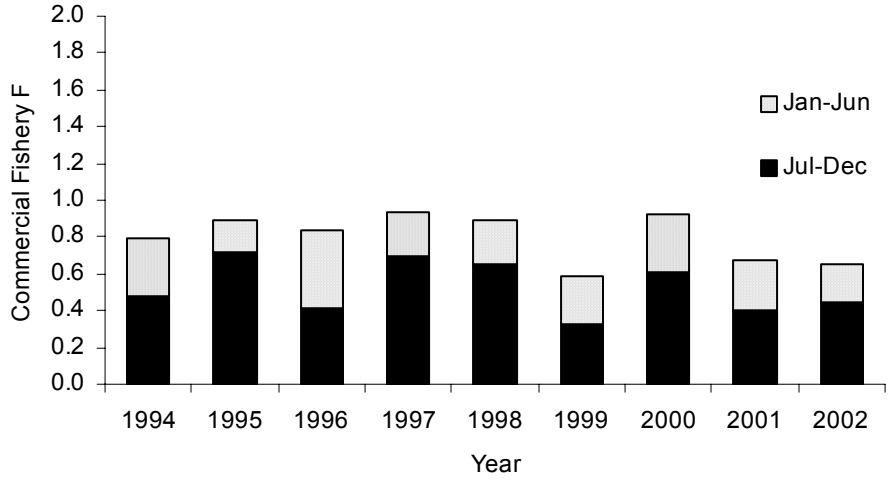

Figure 15. Total commercial fishing mortality ($F_{c\,Tot}$) on fully recruited males divided into January-June and July-December periods (1994-2002).

Table 18. Age specific commercial fishing mortalities (F cJan) on males for the January-June Period.

Age	1994	1995	1996	1997	1998	1999	2000	2001	2002
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	0.02	0.01	0.02	0.01	0.01	0.01	0.02	0.01	0.01
2	0.32	0.18	0.42	0.24	0.24	0.26	0.32	0.27	0.20
3	0.32	0.18	0.42	0.24	0.24	0.26	0.32	0.27	0.20
4	0.32	0.18	0.42	0.24	0.24	0.26	0.32	0.27	0.20
5	0.32	0.18	0.42	0.24	0.24	0.26	0.32	0.27	0.20
6+	0.32	0.18	0.42	0.24	0.24	0.26	0.32	0.27	0.20

Table 19. Age specific commercial fishing mortalities (Fc Jul) on males for the July-December period.

Age	1994	1995	1996	1997	1998	1999	2000	2001	2002
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	0.16	0.24	0.14	0.23	0.22	0.11	0.20	0.13	0.15
2	0.47	0.70	0.41	0.68	0.64	0.32	0.60	0.39	0.44
3	0.48	0.71	0.41	0.69	0.65	0.33	0.61	0.40	0.45
4	0.48	0.71	0.41	0.69	0.65	0.33	0.61	0.40	0.45
5	0.48	0.71	0.41	0.69	0.65	0.33	0.61	0.40	0.45
6+	0.48	0.71	0.41	0.69	0.65	0.33	0.61	0.40	0.45

Commercial Fishing Mortality on Females

Full $F_{c\,Tot}$ on females fluctuated between 1994-1999, and has since remained stable from 2000-2002 (Figure 16). Average fishing mortality on fully recruited females from 1994 to 2002 was Full $F_{c\,Tot}$ =1.25, terminal year $F_{c\,Tot}$ was 1.11. Ninety-one percent of the $F_{c\,Tot}$ on females occurs during the second half of the year. Age specific F_c for each time period are presented in Tables 20, 21.

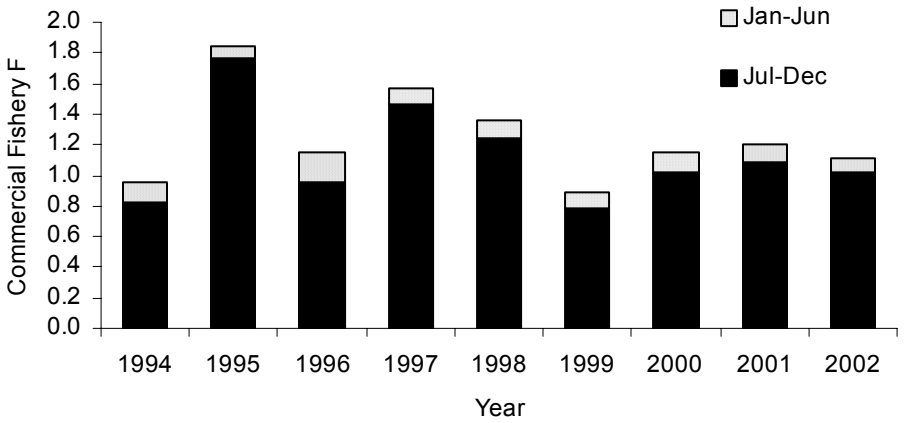

Figure 16. Total commercial fishing mortality ($F_{c\,Tot}$) on fully recruited females divided into January-June and July-December periods (1994-2002).

Table 20. Age specific commercial fishing mortalities (F c Jan) on females for the January-June period

Age	1994	1995	1996	1997	1998	1999	2000	2001	2002
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
2	0.13	0.08	0.19	0.10	0.11	0.11	0.13	0.12	0.08
3	0.13	0.08	0.19	0.10	0.11	0.11	0.13	0.12	0.08
4	0.13	0.08	0.19	0.10	0.11	0.11	0.13	0.12	0.08
5	0.13	0.08	0.19	0.10	0.11	0.11	0.13	0.12	0.08
6+	0.13	0.08	0.19	0.10	0.11	0.11	0.13	0.12	0.08

Table 21. Age specific commercial fishing mortalities (F c Jul) on females for the July-December period.

Age	1994	1995	1996	1997	1998	1999	2000	2001	2002
0	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	0.06	0.13	0.07	0.11	0.09	0.06	0.07	0.08	0.08
2	0.55	1.16	0.63	0.97	0.82	0.52	0.67	0.72	0.67
3	0.81	1.73	0.94	1.44	1.21	0.77	1.00	1.07	1.00
4	0.83	1.76	0.96	1.47	1.24	0.79	1.02	1.09	1.02
5	0.83	1.76	0.96	1.47	1.24	0.79	1.02	1.09	1.03
6+	0.83	1.76	0.96	1.47	1.24	0.79	1.02	1.09	1.03

Recreational Fishing Mortality

The magnitude and timing of recreational fishing mortality (F_r) was similar on both males and females. Overall, F_r was minimal and occurred almost exclusively in the second half of the year (Figures 17, 18). Ninety-one and 90% of the male and female $F_{r\ Tot}$ occurred in July-December. Average full fishing mortality from 1994-2002 was $F_{r\ Tot}$ =0.033 on males and $F_{r\ Tot}$ =0.026 on females. Yearly fluctuations in Full $F_{r\ Tot}$ were mostly due to variations in age 0 recruitment estimates.

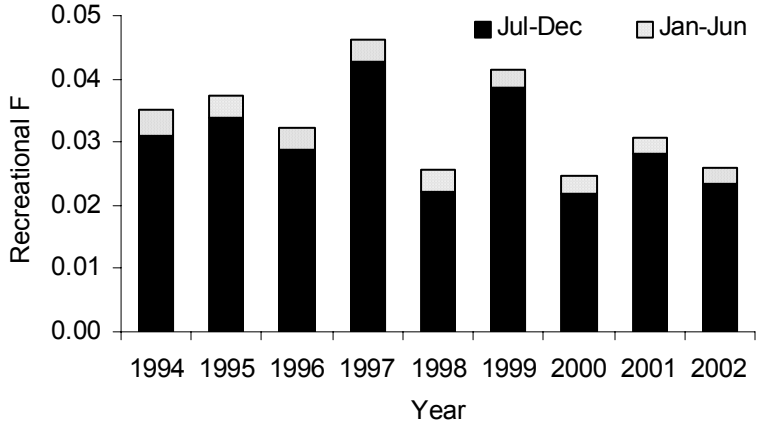

Figure 17. Total recreational fishing mortality ($F_{r\ Tot}$) on fully recruited males divided into January-June and July-December periods (1994-2002).

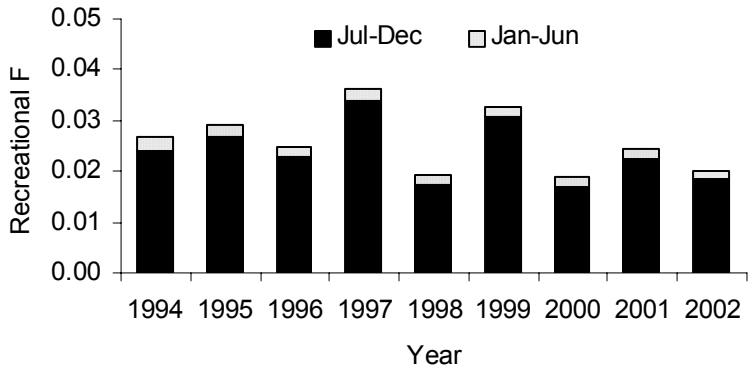

Figure 18. Total recreational fishing mortality ($F_{r\,Tot}$) on fully recruited females divided into January-June and July-December periods (1994-2002).

Average, Full F_r during the January-June period was $F_{r\,Jan}$ =0.003 and =0.002 for males and females from 1994-2002. Ages 1-6+ were fully recruited to the fishery during the first half of the year. Average Full $F_{r\,Jul}$ was 0.026 and 0.020 for males and females and essentially occurred on age 0 fish only.

Combined Fishing Mortality, *F* (Commercial + Recreational Fishing Mortality)

Annual, combined commercial and recreational, age-specific fishing mortalities, ($F_{c\,Jan}$ +$F_{c\,Jul}$ +$F_{r\,Jan}$ +$F_{r\,Jul}$), on males and females are presented in Tables 22 and 23.

Table 22. Full year, commercial + recreational, age specific fishing mortalities ($F_{c\,Jan}$ +$F_{c\,Jul}$ +$F_{r\,Jan}$ +$F_{r\,Jul}$) on males from 1994 to 2002.

Age	1994	1995	1996	1997	1998	1999	2000	2001	2002
0	0.03	0.04	0.03	0.05	0.03	0.04	0.02	0.03	0.03
1	0.19	0.26	0.17	0.26	0.24	0.14	0.23	0.16	0.17
2	0.79	0.89	0.83	0.93	0.89	0.59	0.92	0.67	0.65
3	0.80	0.90	0.84	0.94	0.90	0.59	0.93	0.68	0.65
4	0.80	0.90	0.84	0.94	0.90	0.59	0.93	0.68	0.65
5	0.80	0.90	0.84	0.94	0.90	0.59	0.93	0.68	0.65
6+	0.80	0.90	0.84	0.94	0.90	0.59	0.93	0.68	0.65

Table 23. Full year, commercial + recreational, age specific fishing mortalities ($F_{c\ Jan} + F_{c\ Jul} + F_{r\ Jan} + F_{r\ Jul}$) on females from 1994 to 2002.

Age	1994	1995	1996	1997	1998	1999	2000	2001	2002
0	0.03	0.03	0.03	0.04	0.02	0.03	0.02	0.03	0.02
1	0.07	0.14	0.08	0.12	0.10	0.07	0.08	0.09	0.08
2	0.68	1.24	0.82	1.07	0.93	0.63	0.80	0.84	0.76
3	0.94	1.81	1.13	1.54	1.33	0.88	1.13	1.19	1.09
4	0.96	1.84	1.15	1.57	1.35	0.90	1.15	1.21	1.11
5	0.96	1.84	1.15	1.57	1.36	0.90	1.15	1.21	1.11
6+	0.96	1.84	1.15	1.57	1.36	0.90	1.15	1.21	1.11

Population Numbers-at-Age

The population model simulated numbers at age of the total population by sex and half year, displayed in Table 24.

Table 24. Male and female numbers-at-age estimated in the population model. Values show numbers (in thousands) at the start of each age class. Age class (6.0+) represents all fish >=6 years old on 1 January of that given year. Age class (6.5+) represents all fish >=6 years old on 1 July of that year. The boxed values are intended to illustrate a single cohort through time (e.g. 1994 cohort).

Males

Age	1994	1995	1996	1997	1998	1999	2000	2001	2002
0.0	28,398	25,186	30,100	18,882	40,907	19,956	41,288	18,836	50,566
0.5	6,570	5,827	6,965	4,369	9,465	4,618	9,553	4,359	11,701
1.0	2,344	3,375	2,982	3,586	2,216	4,902	2,356	4,950	2,246
1.5	1,472	2,135	1,864	2,261	1,397	3,090	1,481	3,119	1,421
2.0	702	866	1,160	1,120	1,234	779	1,905	836	1,883
2.5	370	525	552	639	702	436	1,007	462	1,120
3.0	258	174	195	276	242	278	237	416	233
3.5	143	111	97	165	145	164	131	241	146
4.0	103	69	42	50	64	59	92	56	125
4.5	58	45	22	31	39	35	52	33	80
5.0	43	29	17	11	12	16	20	22	17
5.5	25	19	9	7	8	10	12	13	11
6.0+	32	21	13	8	5	4	7	7	9
6.5+	18	14	7	5	3	3	4	4	6
Total	40,537	38,395	44,025	31,410	56,439	34,350	58,145	33,355	69,564

Females

Age	1994	1995	1996	1997	1998	1999	2000	2001	2002
0.0	28,398	25,186	30,100	18,882	40,907	19,956	41,288	18,836	50,566
0.5	8,093	7,178	8,579	5,382	11,659	5,688	11,768	5,369	14,413
1.0	3,166	4,587	4,046	4,867	3,014	6,645	3,203	6,714	3,045
1.5	2,153	3,125	2,747	3,314	2,051	4,524	2,179	4,571	2,075
2.0	1,070	1,481	2,007	1,873	2,171	1,372	3,119	1,481	3,087
2.5	718	1,049	1,267	1,295	1,480	941	2,096	1,008	2,169
3.0	432	326	258	529	386	514	440	841	386
3.5	302	241	170	382	275	368	308	597	283
4.0	187	108	35	54	73	66	138	92	166
4.5	134	82	23	40	53	48	99	67	124
5.0	84	48	12	7	7	13	18	29	18
5.5	61	37	8	5	6	9	13	21	14
6+	72	41	10	5	2	2	4	5	7
6.5+	52	32	7	3	1	1	3	4	5
Total	44,924	43,521	49,267	36,638	62,087	40,147	64,675	39,635	76,360

Age 0 Recruitment

Annual age 0 recruitment (R_0) averaged 61 million over the population model time frame. The highest R_0 estimates occurred in three of the last five years of the

assessment, peaking in 2002 (Figure 19).

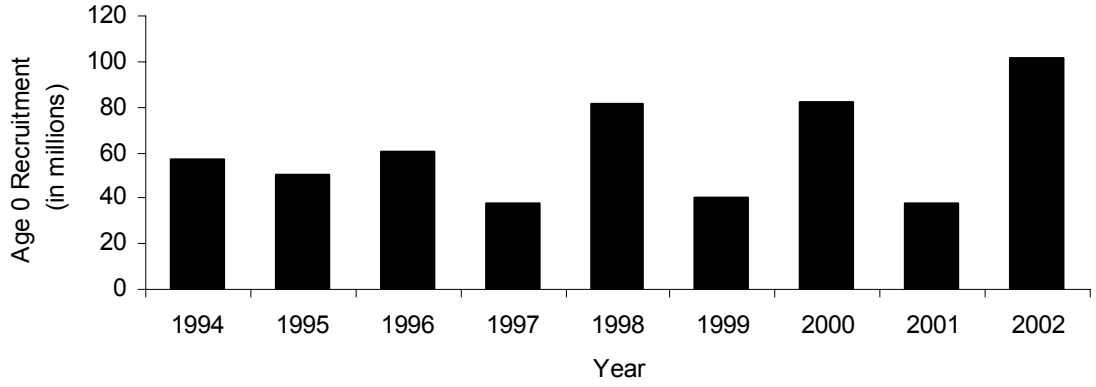

Figure 19. Population model estimated age 0 recruitment.

Population Biomass

Population biomass susceptible to commercial exploitation has risen over the population model timeframe, particularly in the later years of the assessment (Figure 20).

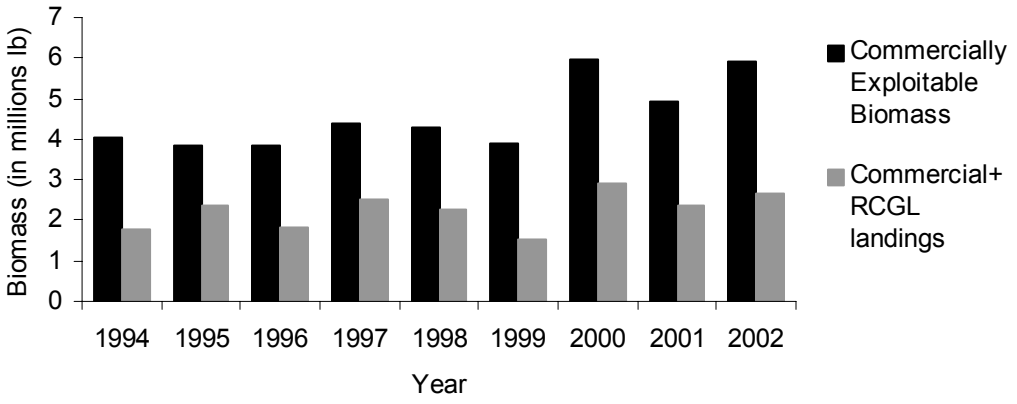

Figure 20. Commercially exploitable biomass in relation to the combined commercial and RCGL harvest (DMF data).

Estimated female spawning stock biomass (SSB) is likewise generally increasing over the time series (Figure 21). Approximately half (55%) of the SSB typically comes from age 3 fish and older (Figure 21). Annual SSB is based on 1 January abundance of mature females from the following year (i.e. 1994 SSB = biomass of mature females on 1 January 1995). Using January abundance accounts for the considerable roe harvest that occurs in the late stages of each July-December period, and assumes that nearly all July-December fishing mortality occurs on pre-spawned fish. The numbers alive at the start of the January-June period was felt to be a better account of the reproductive contributors left after the roe harvest.

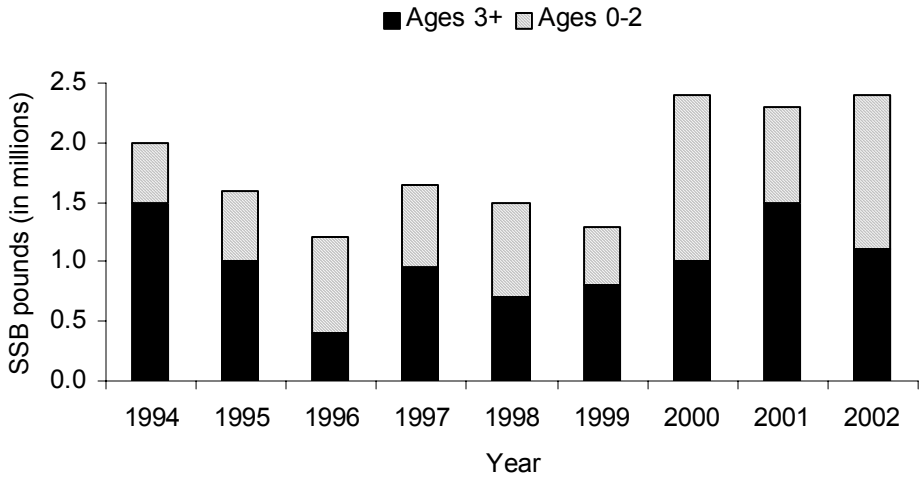

Figure 21. Female spawning stock biomass.

V. Benchmarks

F-based benchmarks for the commercial fishery were determined by employing conventional yield per recruit (YPR) or reproduction-based spawning stock biomass per recruit (SSB/R) models. Due to the very minor magnitude of recreational fishing mortality, $F_{r\,Jan}$ and $F_{r\,Jul}$ were set constant at the 1994-2002 average values for males and females. Commercial fishing mortality benchmarks were based on the assumption that $F_{c\,Tot}$ would continue to be consistently split between each half year as demonstrated over the population model time frame. Observed Full $F_{c\,Tot}$ rates from the population model are shown in relation to the following benchmarks. Fishing thresholds, which will define overfishing, are chosen from among these benchmarks in the Discussion.

Yield per Recruit Benchmarks

Yield per recruit (YPR) benchmarks are designed to maximize yield to the fishery, by balancing the inevitable loss of individuals (due to mortality) with the increasing growth of individuals with age. YPR benchmarks only maximize harvest weight and are not intended to ensure reproductive sustainability of the stock. Commercial and recreational selectivities, von Bertalanffy growth parameters, and age specific natural mortality rates were used in YPR modeling to determine the commercial $F_{c\,Tot}$ resulting in maximum yield per recruit, F_{max}, and the conservative reference point, $F_{0.1}$. Male F_{max} =1.65 and $F_{0.1}$ =0.58 (Figure 22); female F_{max} =1.71 and $F_{0.1}$=0.59 (Figure 23).

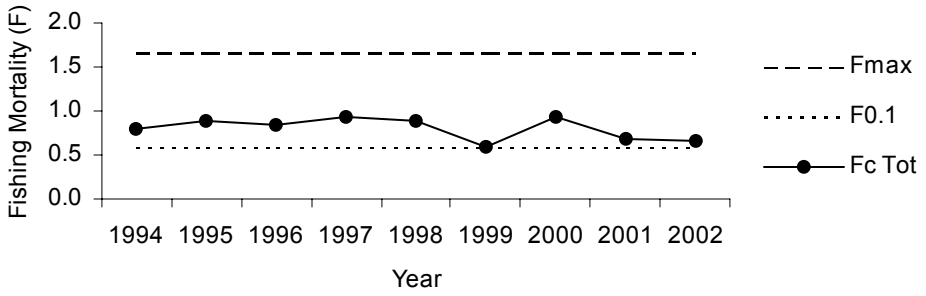

Figure 22. Yield per recruit benchmarks for males (F_{max}, $F_{0.1}$) in relation to observed, full commercial fishing mortality from 1994 to 2002.

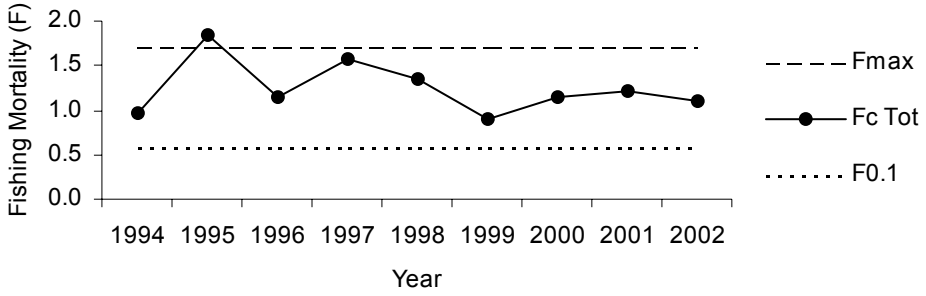

Figure 23. Yield per recruit benchmarks for females (F_{max}, $F_{0.1}$) in relation to observed, full commercial fishing mortality from 1994 to 2002.

Spawning Stock Biomass Per Recruit Benchmarks

Spawning stock biomass per recruit (SSB/R) analysis follows the general rule that increasing fishing mortality leads to decreased reproductive output by the stock. Reproductive productivity of the stock is often measured as spawning potential ratio (SPR). SPR is the weight of the female spawning stock (under fished conditions) divided by the weight of the unfished (F=0), virgin, female spawning stock, represented as a percentage. As an example, $F_{20\%}$ would be the F rate where SPR =20% or where the SSB would be 20% of the SSB if no fishing occurred. The SPR is based on the assumption of equilibrium, that is, where population productivity is viewed under static recruitment, growth, and mortality conditions. The weight sum of all mature females on 1 January was considered the best characterization of spawning biomass for the stock in the SPR calculations. The maturity schedule was based on the model-estimated LVB growth curve and the length-based maturity ogive from DMF data (Table 25).

Table 25. Maturity schedule for female striped mullet.

Age	Maturity
0.0	0.0%
0.5	0.2%
1.0	2.1%
1.5	14%
2.0	47%
2.5	78%
3.0	92%
3.5	96%
4.0	98%
4.5	99%
5.0	99%
5.5	100%
6.0	100%
6.5	100%

Biological reference points of SPR =20, 25, 30, and 35% yielded reference fishing mortality rates for females of $F_{20\%}$=1.65, $F_{25\%}$=1.25, $F_{30\%}$=0.98, and $F_{35\%}$=0.80 (Figure 24). SSB/R analysis was not conducted for males. The commercial fishery has harvested at an *F* rate on females below $F_{25\%}$ (i.e. ≥25% SSB) for the four most-recent years and six of the nine total years of the assessment (Figure 24).

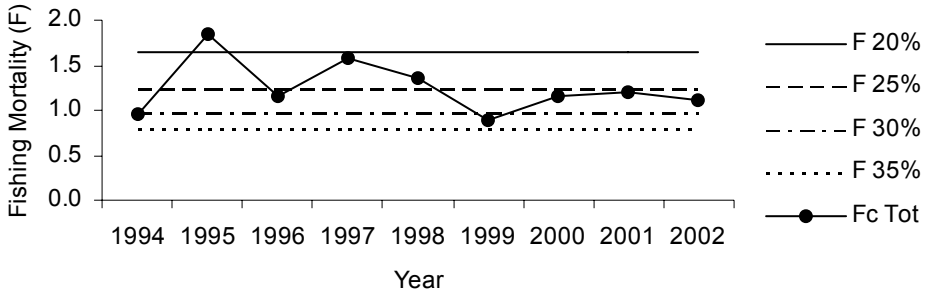

Figure 24. *F*-based benchmarks based on SPR for females ($F_{20,25,30,35\%}$) in relation to observed, full commercial fishing mortality on females from 1994 to 2002.

Replacement Benchmarks F_{med}, F_{low}, F_{high}

F_{med}, F_{low}, and F_{high}, calculated from the relationship between observed SSB and recruitment, were explored as viable replacement benchmarks (F_{rep}) for the stock (Sissenwine and Shepherd 1987; Quinn and Deriso 1999). F_{rep} is the fishing mortality rate that maintains the stock at a level equal to its historical stock size (Sissenwine and Shepherd 1987). Observed SSB was based on total mature females from 1 January periods and recruitment data was based on age 0 recruits (R_0) estimated in the population model. Three replacement lines were calculated from the observed stock-recruit data, each giving the theoretical equilibrium recruitment that replaces spawning stock (Figure 25) (Quinn and Deriso 1999). Replacement lines corresponding to F_{med}, *F*

$_{low}$, and F_{high} were based on historical median recruitment (50% of R_0 values above the line), 25th percentile recruitment (75% of R_0 values above the line), and 75th percentile recruitment (25% of R_0 above the line), respectively. F_{med} was 1.37, F_{low} =1.08, and F_{high} =2.11. Female $F_{c\ Tot}$ was below F_{med} every year except 1995 and 1997 (Figure 26).

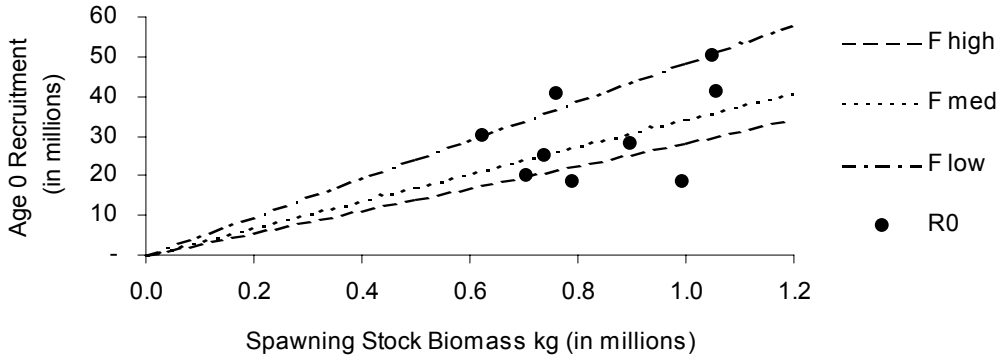

Figure 25. The relationship between female spawning stock biomass and age 0 recruits (R_0) from 1994 to 2002, and the replacement lines corresponding to benchmarks: F_{high}, F_{med}, and F_{low}.

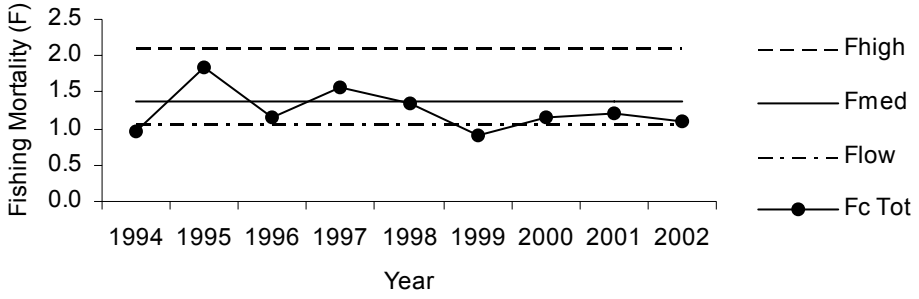

Figure 26. Replacement benchmarks for females ($F_{high, med, low}$) in relation to observed, full commercial fishing mortality on females from 1994 to 2002.

Benchmark Summary

Figure 27 shows $F_{0.1}$ and F_{max} in relation to the YPR curve for males.

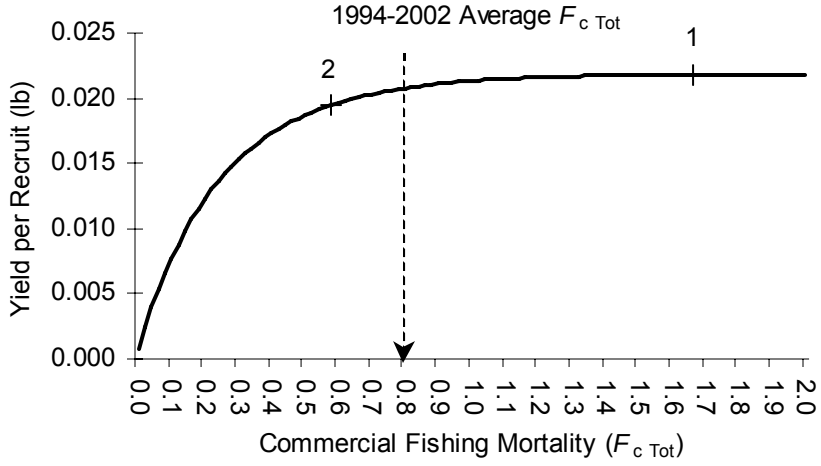

Figure 27. Biological reference points for the male striped mullet stock. 1 indicates F_{max}; 2 = $F_{0.1}$.

Figure 28 shows all benchmark *F*s and the average 1994-2002 female $F_{c\ Tot}$ in relation to the YPR and SPR curves.

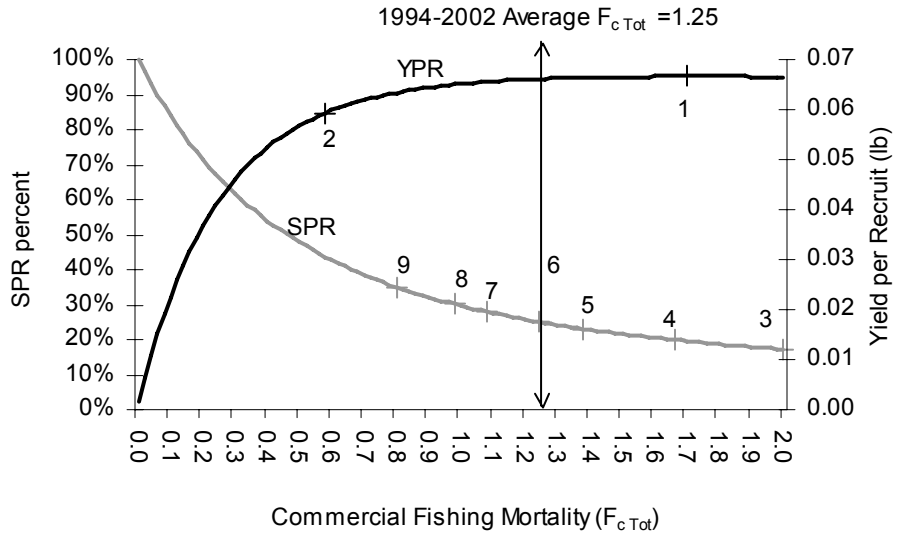

Figure 28. Biological reference points for the female striped mullet stock. 1 = F_{max}; 2 = $F_{0.1}$; 3 = F_{high}; 4 = $F_{20\%}$; 5 = F_{med}; 6 = $F_{25\%}$; 7 = F_{low}; 8 = $F_{30\%}$; 9 = $F_{35\%}$.

Discussion:

Age-growth

The growth curves from age-length key data and from the model-estimated LVB parameters differed considerably for males. More realistic length approximations at early ages were seen in the model-estimated growth curve, given the YOY size information and the resulting model-adjusted T_0 parameter. The very rapid male growth curve observed from the age-length key data may be influenced by poor representation of small specimens (resulting in poorly estimated T_0), or possible otolith ageing error associated with young ages (although this is unlikely to have affected males only). Mahmoudi et al. (2001) infers that striped mullet exhibit a protandric bisexual juvenile stage (all juveniles develop first as males) based on a maturity study in Florida, although other studies have yet to support this assertion. Protandric hermaphroditic transitioning from males to females, rather than higher natural mortality on males, might explain the female-dominated sex-ratio at larger sizes and the lower L_{inf} relative to females. However, further studies are needed to support this hypothesis of hermaphroditism. Wide ranges of L_{inf}, k, and T_0 parameters are found in age-growth studies from Florida, South Carolina, and North Carolina, with little overall agreement between states (Tables 26,27) (Mahmoudi et al. 2001; McDonough 2001).

Table 26. Male von Bertalanffy growth parameters estimated in the population model, from age-length key data, from Florida (Mahmoudi et. al 2001), and from South Carolina (McDonough 2001). a =Indian River, FL b =St. Johns River, FL, c =Lake George, FL, d =Linf given in total length.

Growth parameters	Population Model	Age -Length Keys	Mahmoudi et al. 2001$_a$	Mahmoudi et al. 2001$_b$	Mahmoudi et al. 2001$_c$	McDonough 2001
L_{inf}	403	403	350	301	355	292$_d$
k	0.43	0.50	0.87	0.80	0.99	1.23
T_o	-0.01	-0.38	-0.004	0.40	-0.17	-0.55

Table 27. Female von Bertalanffy growth parameters estimated in the population model, from age-length key data, from Florida (Mahmoudi et. al 2001), and from South Carolina (McDonough 2001). a =Indian River, FL b =St. Johns River, FL, c =Lake George, FL, d =Linf given in total length.

Growth parameters	Population Model	Age -Length Keys	Mahmoudi et al. 2001$_a$	Mahmoudi et al. 2001$_b$	Mahmoudi et al. 2001$_c$	McDonough 2001
L_{inf}	504	504	441	369	569	453$_d$
k	0.41	0.43	0.46	0.44	0.21	0.87
T_o	-0.01	-0.11	-0.227	-0.63	-1.97	-1.51

Maturity

Maturity schedules have a profound effect on reproduction-based benchmarks, as earlier maturity leads to less conservative benchmarks for management. The L_{50} estimate from macroscopically-staged North Carolina specimens falls within the range of histology-based maturity studies in Florida and South Carolina. Fifty percent of females

reach maturity at 314 mm and 320 mm FL in two separate river systems in Florida (Mahmoudi et al. 2001), whereas North Carolina females reach maturity earlier, at L_{50} =305 mm. DMF size at 50% maturity matches with onset at maturity (230 to 270 mm SL) from histologically examined females from northeast Florida (Greeley et al. 1987), and is larger than the L_{50} =276 mm FL from histologically examined females from South Carolina (data obtained from C. McDonough, South Carolina Dept. Natural Resources). Age-at-maturity schedules from North and South Carolina females are fairly similar; 50% of females reach maturity at age 2, while 100% of age 3 females are mature in South Carolina and 92% in North Carolina (97% at age 3.5) (McDonough et al. 2003).

Mortality

Quantitative estimates of total instantaneous mortality, *Z* (i.e. $Z = F + M$), calculated from DMF catch curves and mark and recapture analyses generally agree with the range of *Z* estimates in the population model. Catch curve analyses of annual commercial beach seine landings produced combined-sex *Z* values ranging from 1.08 to 1.69 for years 1999 to 2002 (Table 28). Catch curves were based on ages 1-6 in 1999; ages 2-6 in 2000 and 2002; and ages 3-5 in 2001 (e.g. ages at full recruitment into the beach seine). Although samples sizes were small each year of the analysis (annual ranges: 2-7 trips; 141-877 individuals), annual Z values were still similar to male and female *Z* estimated in the population model over the same age classes (Table 28).

Table 28. Total instantaneous mortality rates (Z) from the population model and from catch curves analyses of the commercial beach seine catch. Ages 1-6 were used in 1999; ages 2-6 in 2000 and 2002; and ages 3-5 in 2001, based on age at full recruitment into the beach seine. Average Z across age classes are given from the population model.

	1999	2000	2001	2002
Model (Males	1.20	1.52	1.64	1.48
Model (Females)	1.07	1.43	1.16	1.15
Catch Curve Analysis	1.12	1.08	1.69	1.16

A tagging study conducted in North Carolina from 1998 to 2001 yielded slightly higher *Z* rates than the population model (Bacheler et al. in review). Using a single-age band recovery model (Brownie et al. 1985), *Z* rates for combined-sex fish $\geq$300 mm FL were *Z* =1.71 and 2.12, depending on the time-dependent analytical approach (Bacheler et al. in review). Average *Z* values over the same time period (1998-2001) and size range (>300 mm) from the population model for males and females were estimated at *Z* =1.25 and *Z* =1.53. Given the female dominated sex-ratio at size classes >300 mm, Z from the tagging study better compares to the female estimated Z from the population model.

Good agreement also occurs between estimated *F* rates from the pre net-ban Florida fishery and the North Carolina fishery. The pre net-ban Florida fishery is the only comparable fishery to the current North Carolina fishery along the U.S. Atlantic coast, in terms of magnitude of landings and commercial gill net usage. Annual *F* (commercial + recreational) rates on the striped mullet stock of the east coast of Florida between 1991-1994, ranged from *F* =1.13 to 1.66 on ages 3-7 (combined sexes) (Mahmoudi et al. 2001). Full *F* (commercial + recreational) observed in the population model for the North Carolina stock ranged from 0.59 to 0.94 on ages 2-6+ males and 0.90 to 1.84 on ages 3-

6+ females between 1994-2002.

Overfishing and Overfished Defintions

Thresholds are often the basis for determining whether *overfishing* is occurring, or when a stock is *overfished*. When fishing mortality rate exceeds the threshold *F* rate, then *overfishing* is occurring and the rate of removal of fish exceeds the ability of the stock to replenish itself (ASMFC 2004). A stock is *overfished* when the reproductive output of the stock is below a threshold level needed to sustain itself (ASMFC 2004). In some cases, overfishing may not be occurring, but the stock may still be overfished, since it may take many years of reduced *F* to rebuild the stock to suitable abundance levels. Similarly, Hilborn (2002) states, *A stock is technically overfished when it is held at a biomass below which maximum sustainable yield will be produced or is fished at a fishing mortality at which yield per recruit is lower than maximum*. Again, these criteria for defining an overfished condition are not always simultaneous, as *F* can often be safely under the threshold *F* that yields maximum YPR, while stock size is still grossly below the level for sustainability.

No reliable estimates of maximum sustainable yield (MSY) could be generated for the stock. Therefore, *F*-based thresholds were to assess the status of the stock in lieu of a biomass-based threshold. Attempts at determining biological reference points based on MSY were unsuccessful. A surplus production model failed to estimate biomass at MSY due to a lack of model convergence; other models were not practical with the currently weak understanding of a stock-recruitment relationship due to the short time series of data.

Overfishing and Overfished Determinations for Males

Current commercial fishing practices allow males to attain adequate weight before being harvested, based on annual commercial fishing mortality rates relative to F_{max}. The male stock is likely not overfished, given how close annual *F* rates lie in relation to $F_{0.1}$, and in view of the fact that fewer males are needed in relation to females for reproduction (and for overall stock sustainability). $F_{0.1}$ is sometimes considered a conservative proxy for fishing at MSY.

Overfishing and Overfished Determinations for Females

Overfishing on females is more complicated to assess than males, and more essential for management, as female abundance is directly related to reproductive output and sustainability of the stock. Current commercial fishing practices on females allow enough growth of individuals to prevent declining yield per recruit (i.e. $F_{c\,Tot} < F_{max}$), however it is not known if SSB is sufficient for sustainability. SPR-based thresholds in lieu of the absence of an MSY estimate can be used as a precautionary management approach (Quinn and Deriso 1999). In general, the higher the SPR, the better precaution is taken in favor of conservation of the stock.

Current fishing practices and fishing mortality rates maintain an equilibrium stock size at SPR =25%, based on the 1994-2002 average $F_{c\,Tot}$ =1.25. More recent annual commercial *F* rates from 2000-2002 maintain between 26-27% SPR from year-to-year. According to the population model, female SSB is expanding and the three highest estimates of R_0 occur in the last five years of the time series. Female $F_{c\,Tot}$ has

stabilized at $\leq F_{25\%}$ for the last four years, as the heaviest exploitation had occurred in the early years of the time series. Elevated age 0 recruitment, less effort in the fishery (1994-1998 average annual commercial fishing trips =13,727; 1999-2002 average =11,482), and a sharp drop in landings in 1999 (Hurricane Floyd) likely accounted for the lowered annual *F*s and led to rising SSB observed in 1999-2002. From an historical perspective, the commercial fishery has sustained landings similar in scope to current levels (with wide fluctuations) for over 100 years (see FMP Description of the Commercial Fishery), with the historical median catch equal to 2,132,301 lb and the 1994-2002 median =2,298,240 lb (average =2,182,721 million lb).

Fishery managers in Florida set a target *F* based on SPR =35% for their eastern coast striped mullet stock (Mahmoudi et al. 2001) based primarily on management precedents from other statewide species (personal communication, B. Mahmoudi). A target *F* based on SPR =30%, with an overfishing threshold of SPR =25% appears justified for North Carolina based on early age at maturity, delayed female exploitation until age 3+, high fecundity (Bichy and Taylor 2002), very large observed age 0 recruitment, unknown egg/larval supply from southern states, and no obvious expansion or decline in landings from a long-term historical perspective.

F_{rep} is another viable threshold *F* for the female stock. This reference point, derived from an analysis of historical stock-recruit data, defines a fishing rate when exceeded for an extended period of time will cause the population to decline (Sissenwine and Shepherd 1987). If compensation occurs (age 0 recruitment increases as SSB increases), then replacement benchmarks become more protective as time moves forward. F_{rep} is an unsuitable threshold if recruitment tends to decline with increasing SSB (depensation), or if the analysis is based on a historical time series when the stock is greatly overexploited. F_{med} is often substituted as F_{rep} (Sissenwine and Shepherd 1987). F_{high} is an unsuitable threshold option due to its lack of precautionary measure, given that this analysis was based on a short stock-recruit time series from a period of a well-developed fishery. F_{low} is a more conservative alternative to F_{med}, since it corresponds to a replacement line where 75% (rather than 50%) of the historical annual recruitment values are achieved. Given the uncertainty due to the short time series, F_{low} has good informative value as a threshold due to its greater precautionary basis. Commercial fishing mortality on females has been below F_{med} for nearly the entire assessment (seven of nine years), and has hovered near F_{low} for the last four years of the assessment. Although the limited time series of stock-recruit data is a caveat to weigh when employing these benchmarks, the calculated F_{med} and F_{low} values appear to be useful thresholds. Replacement benchmarks based on F_{med} =1.37 and F_{low} =1.08 provide additional support for adopting $F_{25\%}$ and $F_{30\%}$ as threshold and target *F* rates for females.

Proxy F_{msy}

An *F*-based commercial threshold on females based on SPR =25% ($F_{25\%}$ =1.25), acting essentially as a proxy for F_{msy}, should be appropriate to maintain the recent harvest level while ensuring the sustainability of the stock. Adequate year-to-year age 0 recruitment should result from fishing at this threshold, given its magnitude in relation to F_{med} and F_{low}. This level of recruitment should theoretically maintain future stock size at the 1994-2002 level. Based on recent estimates of annual fishing mortality in relation to the threshold $F_{25\%}$, overfishing on the North Carolina striped mullet stock is presently not occurring. Fishing mortality on females was highest during the early portion of the

assessment, as overfishing occurred in 1995, 1997, and 1998. Over the second half of the assessment from 1999-2002, F rates stabilized at less than $F_{25\%}$ (1999-2002 average $F_{c\,Tot}$ =1.09).

VI. Management Implications

The stock is currently fished at a level that satisfies the management threshold of $F_{25\%}$, therefore *overfishing* is not occurring. Whether the stock is currently *overfished* is uncertain, but available information points towards a sustainable abundance level assuming $F_{25\%}$ is a suitable proxy for F_{msy}. Over the total nine year time series, the average full $F_{c\,Tot}$ =1.25 is equivalent to $F_{25\%}$. The stock has been fished below $F_{25\%}$ for the past four years, concomitant with high levels of age 0 recruitment.

However, with $F_{25\%}$ as a proxy for F_{msy}, the stock is currently fished near the maximum level that maintains sustainability, thus leaving little room for acknowledged uncertainty in data used in the assessment or against unpredictable future events such as recruitment failures. Also, much of the yearly reproductive capacity of the stock is driven by young age classes (less than age 3), which leaves the stock vulnerable to poor recruitment episodes. The typical management response to dealing with uncertainty is to adopt more conservative benchmarks that are considered precautionary (Haigh and Sinclair 2000). A target benchmark of $F_{30\%}$ =0.98 would be a sensible option as a precautionary threshold for the stock.

Management Options

Two management options appear practical for the stock.

Option 1: Implement a yearly, adaptive, data-based management strategy for the stock that would protect against uncertainty or unpredictability in future events. A well-defined management plan encompassing yearly monitoring of age 0 recruitment indices, adult fishery-independent indices, landings in relation to fishing effort, and size and age structure of the fishery (data that can be monitored without a full quantitative assessment) would be enacted to safeguard against negative uncertainty in the assessment, unpredictable recruitment failures, or changing fishery practices. If data indicate a persistent declining pattern, harvest reductions should be triggered to achieve a threshold as, or more protective than the threshold $F_{25\%}$. Minimum thresholds for survey indices or fishery CPUE would act as triggers for management actions. Adaptive, data-based management, prior to restricting the fishery for solely precautionary purposes, is gaining interest in fisheries management (Hilborn 2002).

Option 2: Develop a schedule to achieve a target SSB consistent with an equilibrium SSB at SPR =30% and subsequently maintain fishing mortality at $F_{30\%}$ =0.98 as a precautionary management measure. In a supplementary analysis, the population was projected to 2010 using starting values from the terminal year of the population model, fixed age 0 recruitment based on the 1994-2002 median R_0, and female $F_{c\,Tot}$ =0.98 (see FMP Population Projections to Achieve SPR =30%). Two projections were executed using two different starting vectors for R_0: using the observed 2002 R_0, and a conservative 2002 R_0 replacement based on the 1994-2002 median R_0. Based on the projections, the stock achieves an equilibrium spawning stock size equal to SPR =30% in 2003. In the conservative projection (using the reduced 2002 R_0 vector), allowable catch (RCGL + commercial landings) would be 2.5 million lb in 2004 and would stabilize

to 2.4 million lb by 2005 at a yearly female $F_{30\%}$ =0.98 (Table 29). In a projection using the unaltered terminal year R_0, allowable catch is higher in 2004-2007 due to higher levels of starting recruitment in 2002 (Table 29).

Table 29. Projected allowable catch (commercial + RCGL) from 2004 to 2010 at a fishing mortality rate of F30% =0.98. Projection 1 uses the terminal (2002) estimate of age 0 recruitment (Ro) from the population model. Projection 2 uses a conservative value of 2002 Ro based on the 1994-2002 median Ro. Ro was fixed at the 1994-2002 median Ro for 2004-2010.

	2004	2005	2006	2007	2008	2009	2010
Projection 1	3,405,720	2,992,685	2,602,960	2,460,229	2,414,109	2,399,147	2,394,899
Projection 2	2,478,304	2,421,862	2,401,215	2,395,039	2,393,717	2,393,296	2,393,189

Future Restrictions and Fishery Selectivity

In general, the commercial fishery targets the largest fish when most of the harvest occurs (e.g. during the roe season). This selectivity pattern is amenable to rather large yet sustainable harvest levels. If future harvest reductions on females become necessary, some caution should be taken not to change this selectivity pattern towards smaller fish. For example, since size appears to be a good indicator of sex, restricted fishing effort on larger striped mullet (i.e. maximum size limit or mesh size) would successfully reduce the harvest disproportionately on females. In this case, managers should monitor the subsequent size structure and magnitude of the affected catch to determine if the fishery has shifted its existing level of exploitation to smaller fish. If the fishery selectivity changes towards smaller, thus younger fish, the threshold *F* will be correspondingly lower. Also, shifting the intensity of fishing mortality into the January-June period (assuming no shift to larger meshes) will result in the increased harvest of smaller fish, lowering the *F*-based thresholds. Ideally, the management strategy to reduce female harvest (e.g. large fish) should be guarded towards causing compensatory changes in the selectivity and timing of the fishery.

External Factors Affecting the Stock

Several factors affect the stock to unknown degrees or in unpredictable fashions. One factor is the unknown extent of egg and larval recruitment from more southern states into North Carolina via the Gulf Stream. Spawning is assumed to occur in offshore waters (Arnold and Thompson 1958; Collins 1985a), which would facilitate northward advection of eggs and larvae from stocks in South Carolina to Florida. Also the prolonged period of YOY recruitment observed in North Carolina could be corresponding to more delayed spawning periods in southern states (DMF unpublished data). Net larval influx would reduce the total dependence on the North Carolina spawning stock for recruitment.

Another factor possibly helping stock abundance is the sporadic occurrence of hurricanes, which sometimes reduces *F* during the peak harvest period and acts to preserve spawning stock biomass. As an example, the lowest female $F_{c\ Tot}$ occurred in 1999 and was below $F_{30\%}$ when Hurricane Floyd hit North Carolina. Although disruptive weather can reduce fishing pressure, reliance on these unpredictable events as a management strategy is not recommended.

The future economics of the roe fishery is a factor that will likely dictate future commercial fishing effort, and largely affect fishing mortality rates since current landings are predominantly composed of roe harvest. The observed decline in fishery trips beginning in the late 1990s coincided with recent declines in roe value (price per lb) (see FMP Description of the Commercial Fisheries). A future explosion in roe value would likely lead to a sharp increase in roe exploitation, as seen in the fishery in the late 1980s. Increased landings would incur higher annual *F* rates, and would most likely exceed the threshold based on the nearness of recent *F* rates to the threshold *F*.

Changes in the commercial fishery could also alter the future outlook of the stock. Shifts towards smaller fish or towards year-round exploitation by the fishery would compromise future sustainability. Targeting smaller fish would reduce spawning stock abundance, as the distinctly seasonal commercial fishery selectivities currently allow for females to attain maturity prior to the occurrence of the full brunt of the fishing mortality (Figure 29). An expansion of the commercial fishery into non-roe, winter-spring-summer months, without a concomitant decline in the already high fishing mortality caused by the roe fishery, would also have a negative effect on future sustainability. Greater exploitation in the January-June period would also result in increased harvest of smaller fish, which would lower the threshold *F* and thus lower the allowable harvest.

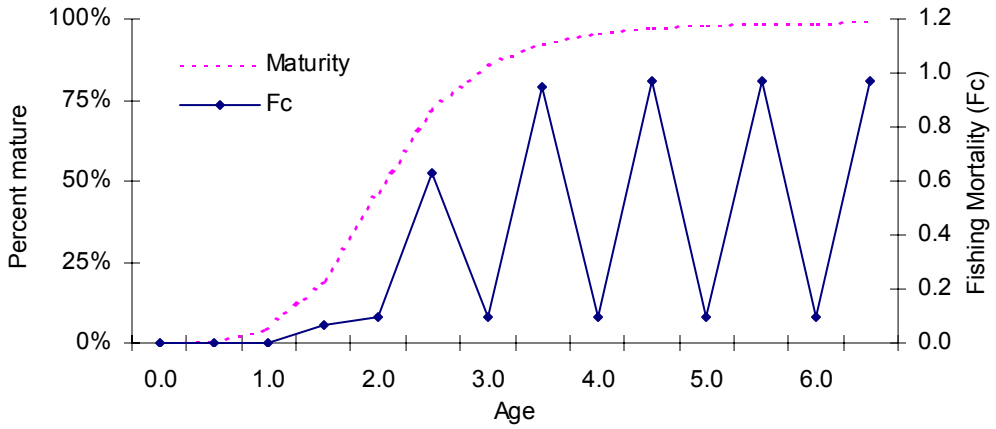

Figure 29. Patterns of female maturity and commercial fishing mortality. 1994-2002 average commercial fishing mortality ($F_{c\,Tot}$ = 1.25) was used to illustrate how the current pattern of fishing selectivity allows maturity to occur before the brunt of the fishing mortality.

Assessment Needs

Improvements in estimating landings statistics by MRFSS are needed for the recreational fishery, as PSE values are large and there is no separation between hook and line versus bait harvest in the data. Although the maturity curve from North Carolina is supported by other studies, a histology-based maturation study would be helpful to further validate the female maturity ogive for the North Carolina stock. A size or age versus fecundity relationship could also further improve the determination of biological reference points for the stock, rather than relying on overall biomass of mature females as a measure of reproductive capacity; although prior studies have shown a poor relationship between fecundity and age for striped mullet (Greeley et al. 1987; McDonough et al. 2003). Further juvenile and adult fishery-independent surveys

specifically designed to monitor striped mullet abundance would benefit an assessment of the stock. Existing fishery-independent surveys should continue to monitor age 0 recruitment and adult abundance, although the trammel net survey has large variability in catch per effort. The development of a spawner-recruit relationship with increasing time will improve the determination of appropriate reference points for stock sustainability.

Model Uncertainty

The population model provides estimates of abundance and harvest rates based on sound analyses and best available data. The complexity of the population model structure (e.g. split sexes, half-year time steps, age variable *M* rates, multiple fisheries and surveys) deterred the use of bootstrapping or other iterative simulations for the quantitative assessment. Typically, variance around parameter estimates has not been produced in recent assessments (Canary, Bocaccio, Darkblotched, and Yelloweye Rockfish) using stock synthesis by National Marine Fisheries Service. A new version of stock synthesis II is currently being developed using A. D. Model Builder as the model tool (pers. comm. R. Methot), which will be able to generate variance values around parameter estimates. However, variability in data used in the model is quantified and incorporated into the assessment by weighting likelihoods using standard error around annual index values and sample sizes of annual length and age information. Different model configurations and sensitivity analyses testing four different fishery CPUE, upper and lower estimates of *M*, fixed *M* across ages, fixed LVB parameters, unrestricted sample sizes for age and size compositions, weighted likelihood components, and inclusion of various other data sources have depicted very good stability in the population model (Table 30).

Table 30. Terminal year estimates of male and female full commercial F and female spawning biomass resulting from various model configurations and sensitivity analyses.

	Default	No fishery CPUE	Runaround CPUE	Set Met CPUE	M-10%	M+10%	Fixed LVB	2002 JAI removed
Terminal Full Year F (Males)	0.65	0.66	0.60	0.71	0.62	0.63	0.24	0.62
Terminal Full Year F (Females)	1.11	1.10	1.10	1.11	1.11	1.11	1.11	1.11
Terminal Spawning Biomass (Females)	1,047,910	1,008,775	1,020,091	971,397	962,290	1,080,119	1,239,639	1,034,778

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